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THE GENESIS OF SCIENTIFIC METHOD, HISTORICALLY VIEWED.

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THE FIRST FRUITS.—The things of mathematics that we regard as the simplest, and the first to be taught to mathematical beginners, were by no means the first things to appear in the historical evolution of race culture in mathematics. The uses of ratio, proportion, squares, square root, doubling, halving, and the arithmetical and geometrical progressions are the earliest mathematical possessions of the race. The employment of these techniques appears in the earliest document of mathematical history that we possess. These processes antedate by many centuries a knowledge of the processes of addition, subtraction, multiplication and division. This is only one of the earliest examples of the fact that historical order of emergence is *not* a criterion of curriculum order of techniques and topics for our day.

A FIRST OCCURRENCE.—But the purpose of this paper is to set forth some of the early aspects of procedure which the users regarded as scientific method. The attentive study of the history of mathematics discovers some aspects of more than passing interest of what students of the day regarded as scientific method. Some readers, at least, may not have thought of these things just the way they are given here.

When the makers of a Babylonian tablet that dates somewhere between 1600 B. C. and 2300 B. C. fitted the terms, 5, 10, 20, 40, 80, of a geometrical series to the areas of the visible illuminated parts of the moon's disc from day to day for the first five days of the month, and then the terms, 96, 112, 128, 144, 160, 176, 192, 208, 224 and 240, of an arithmetical series to the

disc-areas for the next ten days, they were preparing for us the earliest recorded sample of scientific method.

The areas of the visible illuminated lunar disc from day to day were an oft-recurring, orderly sequence of natural phenomena, a quantitative regularity, that appealed to the imagination and interest of the early student as worth recording for future use. The reason for his feeling of the worthiness of this sequence for record was perhaps due to the fact that the student belonged to a race of worshippers of the heavenly bodies. He cast about for a device for making an enduring record. He already knew the arithmetical and geometrical progressions as ordered number sequences. He had long been using number to record individual items of magnitude and quantity. The fitting into a one-to-one correspondence of the items of the phenomenal sequence to the terms of a composite geometrical-arithmetical sequence was a forward stride epoch-making in purport. It is our first historic example of the deliberate application of mathematical law to ordered scientific facts, or of real *objective scientific method.*

This first high scientific act was the beginning of the age-long effort to give mathematical expression to the quantitative regularities and situations of nature. The fact that the fitting was empirical is of secondary import; the excellence of the "fit" and the subsequent usefulness of it in prediction and permanent recording, are of prime consequence. The two latter considerations made the early workers want to repeat the performance. Practical utility and pure scientific appreciation were both present and functioning at the birth of scientific method. These two functionaries had not yet learned to quarrel for primacy in promoting scientific advance.

A SECOND OCCURRENCE.—The early conception of scientific method which consisted in fitting a long and well known number relation or law to a world situation recognized as quantitative, found another striking example when "Thales amazed the Egyptian king by measuring the height of a pyramid by means of its shadow" by putting the four involved magnitudes into order under the law, "as the length of the shadow of the stick to the length of the stick, so is the length of the shadow of the pyramid to the height of the pyramid."

The element in this occurrence that constituted the "genuine stroke of genius" in Thales was the recognition on his part that the problem of measuring the height of a pyramid was a situa-

tion to which the age-old proportion-law was appropriate. This law so long known to the Egyptians but only recently learned by Thales, and still nascent and usable with him, was merely recognized as applicable. The Egyptians probably had learned it as mere abstract truth which, being a part of their sacred literature, was not learned to be desecrated by gross human uses. The obvious point to the episode is that the method of scientific discovery was here for a second time, the mere empirical fitting of a known number law to a phenomenal situation.

A THIRD OCCURRENCE.—A third early example of the same aspect of application of scientific method was that for which Thales was exalted by his countrymen to a place among "the seven sages of Greece." This is the occurrence for which Thales received his ancient honorary "doctorate of philosophy." Thales had brought along from his sojourn in Egypt a table of eclipses that had been made centuries before by the Egyptians, or Chaldaeans. The table stated that solar eclipses recur at regular intervals of about 18 years and 11 days, and gave a list of many past eclipses. Here was a known number sequence again. From it Thales predicted the time of occurrence of the next solar eclipse. The event fulfilled the prophesy sufficiently closely to give him the rank of "seer." Though his contemporary countrymen credited him with superhuman sagacity, subsequent scientists have sought to disparage his fame for the performance on the ground that anyone could have done it with the aid of his tables. Nevertheless Thales was the first Greek to make such use of the ancient eclipse tables. The point here however, is that this performance of fitting a known number sequence to a phenomenal sequence exemplifies the same sort of application of scientific method and called for exactly the same type of scientific acumen and *acumen* is the right word, as did the two preceding samples.

A FOURTH OCCURRENCE.—A fourth outstanding example of the same sort of application of scientific method was the discovery by Pythagoras that the law of squares and square roots applies to the sides of a right triangle. The reader has been already reminded that the law of squares of numbers was among the earliest mathematical possessions of the race. This law was well known and highly prized in Pythagorean arithmetic. The right triangle was also a pet theme with the Pythagorean

geometrical scholars. After many fruitless attempts to discover the law of sides of a right triangle Pythagoras was so overjoyed at the success of his final discovery that the law of side-lengths is covered by the old and familiar law of squares, that he is said to have sacrificed a *hecatomb*. Here again is an early sample of the scientific method of fitting a known number-law to a phenomenal situation. The great success of this undertaking may have been the main stimulating cause of the subsequent distortion of Pythagorean arithmetic into that mystical philosophy which made number, first the *basis* and latterly the *cause* of natural phenomena.

The theory of music which so preoccupied the Pythagoreans was mainly the determining of the lengths of strings that would vibrate agreeable tones, or harmonious tones. This study was merely ascertaining the ratios of string-lengths that would vibrate the octave, the third, the fifth, etc., which again was fitting the old law of proportion to the phenomenal causes of sensations. All these successes led the Pythagoreans to the conclusion that the science of number, arithmetic, must furnish "the explanation of the order and harmony of the universe." This conception led the Pythagoreans to conclude that "number is the cause of form," "the properties of the number 5 are the cause of color," and similar mystical associations and conjectures.

The arithmetic growing out of these mystical associations was of course very soon entirely discarded by subsequent Greek mathematicians, and this is moreover the only part of Pythagorean teachings that have been subsequently discarded. Be it noted however, that Pythagorean arithmeticians set out under the entirely laudable ambition of finding as many number laws as possible, to the end that some of them may sometime be found to fit natural situations and phenomena. They merely allowed a rank lateral growth go to seed in mysticism. No nation has ever showed a higher regard for objective thinking and conclusion-drawing than the Greeks, and this example of the Pythagorean mystical conjecturing in mathematics served them for ages as a bad example of purely subjective procedures. They merely failed to make a sufficient number of "check-ups" on phenomenal situations.

A FIFTH OCCURRENCE.—After Anaxagoras had made classic the problem of finding the side of a square whose area

equals the area of a circle of known diameter, the problem always remained an irritant to the scientific Greek mind. The very formulation of the problem, be it noted, grew out of the circumstance that the law of squares was an historical inheritance. None of the numerous attempts of later Greeks to apply the law of squares to circles, lunes, triangles, etc., got them any farther toward the desired solution than "the areas of circles are as the squares of their diameters and of their radii." The *reductio ad absurdum* procedure of Hippocrates, invented expressly to use on the problem of squaring the circle, was not able to crack the nut. Accordingly Antiphon and Bryson undertook to devise a new method of attack on the difficulty.

A SIXTH OCCURRENCE.—The Greeks' way of building their new "Method of Exhaustions" is a curiously ingenious composition of several anciently known laws of number. From Egyptian times the halving and the doubling processes were known. Out of these two processes, the laws of squares and square roots and the Pythagorean principle of the sides of a right triangle, by this time well-known, they developed a procedure for attacking the problem of the area and the circumference of a circle that created an epoch in Grecian scientific research. The new method was a process of inscribing and circumscribing a regular polygon, calculating their areas and perimeters, doubling the number of sides of the polygons and then repeating the process until they "pinched in" the perimeter of the circle between the perimeters of the polygons and the area of the circle between the polygon-areas. By carrying the doubling process farther and farther they could approach the circumference and area of the circle from both above and below, as closely as they chose. To show their mode of conception in formulating the new method, be it noted here that Bryson injected the gratuitous assumption that "betweenness" must mean "arithmetical mean betweenness" and that the circumference is the arithmetical mean of the perimeters of the inscribed and circumscribed polygons and that the area of the circle is the arithmetical mean of the areas of the polygons. Clearly the role of empiricism had not yet disappeared from the formulation of their procedures. It took the wonder-working mathematical genius of Eudoxus a few years later to purge the new procedure of Bryson's gratuitous assumption and to reduce the Method of Exhaustions to the valid and reliable instrument for

mathematical research, the sound scientific method that it afterwards became. Later in the hands of Archimedes, the new method became a powerful aid in the fitting processes of mathematical laws to natural pnenomena and spatial forms.

A SEVENTH OCCURRENCE.—Aristarchus was deeply interested in the classic problem of his day, viz., that of determining the relative distances of the sun and moon from the earth. He was familiar with the Pythagorean law of the side-lengths of right triangles. It occurred to him that at the instant of the first quarter phase of the moon the distances of the sun and moon from the earth are the sides of a right triangle, right-angled at the moon. The law of Pythagoras would fit the situation. He made the "fit" and thus calculated the best value that had yet been determined for the ratio of the distance of the sun to that of the moon from the earth.

This method of fitting a well-established mathematical law to a situation in nature at once became so much more convincing as a method of establishing astronomical truths than the prevalent philosophical procedure as to produce a new era in astronomy. Astronomical methods now became mathematical and scientific in the modern sense. For this high scientific service of Aristarchus, contemporary religious authorities threw him into prison for the impiety of advocating that the sun and not the earth is the center of the solar system. This also occurred in the much-lauded age of Pericles who was a friend of Aristarchus. The real reason for the imprisonment was probably indirectly to do injury to the unpopular Pericles. Verily there were "anti-evolutionists" also in those days. The great service of Aristarchus was to convert mystically speculative astronomical method into sound scientific method. That his service outlived him witness the fact that the next great astronomers, Eratosthenes and Hipparchus, followed his methods. The magic principle that wrought the method-change was the simple fitting of a known law of numbers to a phenomenal situation.

Never afterwards among the Greeks were the speculative procedures of the Pythagoreans or of Aristotle applied to astronomical studies without first establishing a firm basis of observational and metrical fact.

AN EIGHTH OCCURRENCE.—Archimedes knew not only the ancient ways of getting square roots, but from his calculatory work it would seem that he had some highly expeditious method

of his own of extracting square roots approximately. In his day the long-standing classic problem of "squaring the circle" was still intriguing the attention of mathematicians. Archimedes grappled the difficulty, and though he did not solve the problem, he made progress with it. He proved first that the area of a circle is equal to the area of a *triangle* whose altitude is the radius and whose base is the circumference. Next he proved that the area of a circle is to the area of the circumscribing square as 11 to 14 nearly. Then he altered the conception of the classic difficulty to "calculating the ratio of the circumference to the diameter," i. e., to what we call the problem of calculating π.

This problem of squaring the circle was to Archimedes a real world problem, a phenomenal situation. He proceeded by inscribing and circumscribing regular polygons of the same number of sides, drew lines to analyze the complex situation into basic elemental right triangles, then by "fitting" the Pythagorean theorem to the right triangles he calculated that $3\frac{1}{7} > \pi > 3\frac{10}{71}$. This was one of the ranking mathematical achievements of the ancients, and is again a sample of the deliberate "fitting" of a known mathematical law to a phenomenal situation.

These eight samples are sufficient to impress one with the fact that scientific method, conceived as a "fitting" process of a known number or magnitude law to a quantitative situation or regularity of nature, was successfully practiced by the ancients, and that it is in fact nearly or quite as old as recorded mathematical history. It was practiced especially successfully by the ancient Greeks.

The step from this ancient "fitting" process to the modern process of fitting an empirical equation to a phenomenal situation is mainly a mere symbolic one. The definite procedure of calculating the arbitrary constants of the empirical equation is merely a bit more systematic, but the fundamental thinking involved in both processes is the same.

Perhaps the reader will say that this fitting procedure is all that the *modern* objective scientific method means. If this is true we owe much more to ancient scholarship, particularly to Greek scholarship, than modern scientific writers commonly admit. Naturally, the work of careful observation, patient collecting and recording of facts, are essential beginnings of science, but even this was essential to reveal to the ancients the quantitative regularities and situations calling for the act of

"fitting." The supremely difficult scientific act however seems to be, and always to have been, to *discern the aptness of the "fit."* Herein consists the "discovery." This it is that calls for the stroke of genius, and seems a many times more difficult step to take than it appears to be after the "genius stroke" has been exerted. In other words, it requires a vastly higher order of genius to discern for the first time the propriety of the number law that yields the "fit" than it does to comprehend it, or even to realize its significance and to employ it successfully after the model is set.

AVON, OLD FARMS, AVON, CONN., A JUNIOR COLLEGE AND PREPARATORY SCHOOL FOR BOYS.

It is announced that some $3,000,000 have up to now been expended on the construction of a school and junior college for boys at Avon, Old Farms, Connecticut, by the Pope-Brooks Foundation of Farmington. This sum was given by Mrs. John Wallace Riddle of Farmington and New York for the establishment of a memorial to her father and mother, Alfred Atmore Pope and Ada Brooks Pope.

Mr. Stephen P. Cabot, former head master of St. Georges School at Newport, R. I., as executive regent who is organizing the school, announces that plans are being perfected for the opening of the institution next fall.

At the present time Pope quadrangle, with complete equipment for 200 boys, is finished. Twenty other buildings have also been erected. They are designed in a medieval English domestic style with deeply recessed windows, casements and hewn oak panelling in the rooms. The atmosphere is one of beauty, strength and permanence and will, it is hoped, stimulate the æsthetic feelings of the students.

The school will be operated on a non-profit making basis and will accommodate, when completed, 400 students. The buildings, now nearly completed, are on a 3,000 acre estate which is the gift of Mrs. Riddle who is known as an architect under her maiden name of Theodate Pope. The land is divided into three subdivisions: the park, the forest and the farm. While the cultural phases of education will be the main body of work carried out in the school, a special feature of the work will be an effort to encourage all students to participate in work on the land.

One of the basic principles to be installed at Avon is that a well rounded development during the school years includes a knowledge and the discipline of manual labor. For this reason the farm and the park will be under the direction of a man trained in an agricultural college who has also had experience in teaching. In like manner the forest will be under the direction of a skilled forester. The same principle of having experts who will also be teachers will apply to the power plant, the smithy and the carpenter shop.

Avon students will find these men available for conference and while formal courses will not be given to their subjects, it is felt that a great deal of experience and practical information will be derived by the students.

THE USE OF BRITISH UNITS IN THE TEACHING OF MECHANICS.

A Report by the Educational Committee of the American Physical Society.

Confusion of two kinds exists in the application of the ordinary equations of mechanics to numerical problems. One kind is due to the fact that teachers and also textbooks do not agree on matters of fundamental importance. For example, in the use of the British Gravitational, or Engineering, system there is a difference of opinion regarding the unit of *mass*. This difference leads to two different sets of equations, really two different systems in which the factor g (acceleration of a falling body) is used in different ways. These two systems are frequently confused. In fact, many do not realize that there are two different systems of units known by the same name. Evidence of the confusion can easily be found by examining texts of physics and of applied mechanics and engineering handbooks. Many technical writers fail to handle with certainty such things as momentum and moment of inertia when using British Engineering units. In fact the formulas for some of these quantities as given in textbooks on applied mechanics do not agree and do not lead to the same numerical values.

The other kind of confusion is found in the minds of students in the first college courses. These students have much trouble in learning to distinguish between mass and weight and to use correctly important equations in solving simple problems. For example, many students can not solve such simple problems as the following. Find the force in C.G.S. units which is necessary to lift a kilogram with a vertical acceleration of 200 cm./sec^2. Find the force in pounds which is necessary to lift a 10-lb. weight with a vertical acceleration of 10 feet/sec^2. Knowing this weakness there is often an unconscious tendency on the part of a teacher or a of textbook writer to avoid confusing problems. Is this necessary?

Part of the difficulty is due to the fact that we try to teach students too much. It is not uncommon for several different systems of units involving different fundamental equations to be taught to the same class. Is it necessary to use four different systems of units to teach one set of principles? Would there not be a distinct gain in simplifying our methods? The

first cause of confusion mentioned would be greatly reduced if we agreed to teach the same British Gravitational system, or at least to apply the name British Engineering to only one system.

The Educational Committee of the American Physical Society has been considering the question and presents here a partial report. This report applies only to the teaching of mechanics. It does not include the bearing of this on other branches of physics or engineering. Nor does this report try to settle the many controversial matters connected with our fundamental concepts and definitions. It presents merely an outline of conditions and makes some simple suggestions.

In this report, the term "system of units" means more than a collection of the names of units. The expression includes a logical system of definitions and equations. The electrostatic and electromagnetic C.G.S. systems are examples of systems of units. On the other hand the expression "the metric system" does not refer to a "system" in the sense used here. The essence of a system of units, as the expression is here used, is the choice of units specially designed to give convenient values to the constants, or proportionality factors, appearing in the quantitative statements of the laws. A system includes certain fundamental units, a series of derived units, and a number of equations.

Whenever a system has been logically constructed it is often an important matter in the solving of problems that it be consistently followed. For example, it leads to a clearer understanding of the methods if a student in solving a problem adopts a definite system of units and sticks to that system. In other words, the mixing of systems or the passing from one system to another by a mere juggling of some factor should be avoided. Even in using the C.G.S. Absolute system there is frequently some confusion due to the mixing of units. In this system the gram is the unit of mass and not of force. The gram is a unit of force in a different system, in which some of the fundamental equations are different. Hence, if we are using the absolute units, the gram should be used as a force unit with caution. Some teachers never use a gram as a force unit nor permit their students to do it. In general, systems should not be mixed and a student should be encouraged to understand thoroughly the system he is using.

In the teaching of mechanics in a first college course it must be continually kept in mind that we are teaching the *principles* of mechanics and that we should avoid all unnecessary methods and details. A system of units is a tool and the teaching of it should be justified only by the need for it. All the principles of mechanics could be taught with the use of but one system of units, the C.G.S. Absolute system. However there are two important reasons why the use of a system containing practical units should be taught. (1) The student learns practical applications more readily. (2) A principle can be made more concrete to the student when familiar units are used. (This important pedagogical principle that new ideas should be approached through things which are concrete and familiar to the student is believed by many but practiced by relatively few.) These reasons should be kept clearly in mind in deciding what British systems should be taught.

The systems of units used in mechanics differ in two fundamental ways. The "absolute" systems take as the fundamental qualities *mass, length,* and *time,* while the "gravitational" systems use *force, length,* and *time.* Both schemes are logical, and since the International Conference of 1901 defined the weight of the International Kilogram at a place where $g=980.665$ cm./sec.^{2} as an International Unit of force, both schemes have a definite basis. The other way in which systems differ is in the choice of the proportionality factor in the equation, $F=kma$. This last point is sometimes overlooked. In most textbooks of physics a number of equations are derived on the supposition that $k=1$. But in several systems k is not equal to unity and those equations are no longer correct and must be modified. One of the most common of these equations is the one for kinetic energy. This will be better explained by the following synopsis of different systems. Since most of the trouble seems to be with the use of British systems, only these are explained.

The British Absolute System.

In this system *mass* is regarded as a fundamental quantity and *force* is a derived one. The factor k is set equal to unity and regarded as dimensionless. This is exactly the same procedure as in the C.G.S. Absolute system. Hence the fundamental equations are the same as those in the C.G.S. system.

Quantity	*Name of Unit*
mass	pound
force	poundal
work	foot-poundal

Advantages of this system: 1. It is so similar in construction to the C.G.S. Absolute system that it brings in no special difficulty; it does not confuse one familiar with the C.G.S. system.

2. Its equations are the same as those used in the C.G.S. Absolute system.

3. It uses a familiar unit, the pound, in accord with a common method of measuring commodities. (This is a disputed point. Some insist that people do not understand the concept of mass (inertia) and hence do not use it, but that people are familiar with weight (earth-pull) and hence use it to measure commodities. According to this point of view a pound is in popular usage a unit of weight and not of mass.)

Disadvantages: 1. It is a system which is never used outside of textbooks. The student will never again have occasion to use it.

2. Strange units are used to measure force, weight, and work or energy.

3. Only in rare instances do engineers have occasion to measure or even to be interested in the mass of bodies. But they are much interested in forces and frequently measure them, using the pound as the unit. In most practical work the pound is a unit of force. To teach students something else is not only bad pedagogy but it leads them to believe that the principles and methods of physics are not closely correlated to everyday life.

4. It is hard to use this system consistently either in a textbook or in a class room. For example, it would be objectionable to use the poundal in problems in statics.

5. Two reasons have been given for the teaching of a British system to elementary students, (1) the student learns practical methods, and (2) the student uses units and terms with which he is familiar and thus learns more readily the principles involved. Neither of these reasons apply to this system.

6. Every student has a muscular sense by which he can roughly measure force. He is familiar with the concept of a force, but not that of mass. The choice of mass as a funda-

mental concept is not a wise one from the point of view of a beginner.

British Engineering A System.

There are two British Engineering systems in use. For convenience these will be referred to as the A and B systems. Both of these are used in texts in physics and texts in applied mechanics. In both systems, *force* is taken as a fundamental quantity and *mass* as a derived one. The two systems, however, use different values of the proportionality factor k and hence some of their fundamental equations are different.

The A system, like the absolute systems (C.G.S. and British), is based on the fact that the constant k is made equal to unity, thus obtaining

$$F = ma$$

In this system the *pound* is the unit of *force* (not of mass). The pound is defined as the *weight* of 1/2.204622 kilogram at the standard locality ($g = 32.1740$ ft./sec.^{2}). The unit of work is the *foot-pound.*

All the equations which hold for the C.G.S. Absolute system apply in the A system. No new equations are needed.

Force	$= ma$	*Moment of inertia*	$= \Sigma mr^2$
Kinetic energy	$= \frac{1}{2}mv^2$	*Torque*	$= I\alpha$
Momentum	$= mv$	*Rotational kinetic energy*	$= \frac{1}{2}I\omega^2$

The *slug* or *gee-pound* is sometimes used as the name of the unit of mass. But the use of either of these names is not an essential part of this system. A name for the unit of mass may be used or not. In either case

$$\text{Mass} = \frac{\text{Weight}}{g}$$

an equation which is also true in the absolute systems. Although weight and g vary from place to place, the above ratio remains constant for any one body. Hence the local values or those for any place may be used. In accurate work the weight should be taken as the weight at the standard locality where $g = 32.174$ ft./sec.^{2}, thus avoiding the need of making local determinations of these quantities.

In solving problems it is customary to substitute for mass in all equations where m appears,

$$\text{Mass} = \frac{\text{weight in pounds}}{g \text{ in ft./sec.}^2}$$

For example, when *pounds*/32 is substituted for m in $\frac{1}{2}mv^2$ and the value in feet per second is substituted for v, the result is in foot-pounds.

Advantages: 1. It is not necessary to use any unfamiliar units. The units of force, work, power, etc., are those used in practical work.

2. It is believed that the use of this system reduces to a minimum the doubt as to when and how to use the factor g.

3. It does not confuse students by using the same name for different units.

4. The equations are the same as those in the C.G.S. Absolute system, hence the two systems can be taught simultaneously with a minimum of confusion.

5. It is necessary for the student to learn the difference between *mass* and *weight*, as in the C.G.S. system.

6. There is less chance for confusion in the definitions of such things as momentum and moment of inertia.

7. This system is used in most of the more widely used texts on applied mechanics.

8. Two reasons were given earlier in this report for the use of a British system. Both of these reasons apply to this system.

Disadvantages: 1. The unit of mass which is sometimes used with this system is an unfamiliar one.

2. Many who use this system employ no name for the unit of mass. Many teachers think that mass is such an important concept that the unit should be named and more emphasis given to this concept.

3. Some think that first-year students should not be required to distinguish between *mass* and *weight*.

The British Engineering *B* System

In the *B* system the constant k is set equal to $1/g_0$, where g_0 is the value of the acceleration at the standard locality, $g_0 = 32.1740$ ft./sec.^{2} Hence the fundamental equation is

$$F = \frac{1}{g_0} ma$$

In the special case where the force acting on a mass m is equal to the weight of the mass and produces an acceleration g,

$$\text{Weight} = \frac{1}{g_0} mg$$

Or,
$$\frac{w}{g} = \frac{m}{g_0}$$

Hence the mass of a body is numerically equal to its weight at the standard locality and approximately so elsewhere. Mass and weight are measured by the same unit, the *pound*. The unit of work is the *foot-pound*. Other important equations are,

Momentum $= (1/g_0)mv = (w/g)v$
Kinetic energy $= (1/2g_0)mv^2 = (1/2g)wv^2$
Moment of inertia (I) $= \Sigma(1/g_0)mr^2 = \Sigma(1/g)wr^2$
Rotational kinetic energy $= \frac{1}{2}I\omega^2$
Torque $= I\alpha$

Some writers omit the factor g_0 in the expression for moment of inertia and insert it in the last two equations.

Advantages of the B system: 1. The names of all the units are well-known terms.

2. The unit of mass is not nameless, as is common in the *A* system.

3. Since mass and weight are numerically equal (at least approximately) it is not necessary for the student to learn the difference.

4. Of the units of length, time, mass, and force only the unit of force is different from those used in the British Absolute system. Hence it is possible to solve many problems by using British Absolute units and then by the use of the factor g convert the answer into Engineering units.

Disadvantages of the B system: 1. Several of the important equations are different from those used with the other systems and usually different from the better-known forms.

2. The student has difficulty in remembering where and how to use the factor g. As he frequently does not understand the difference between mass and weight, the process appeals to him as a juggling operation.

3. Students have a tendency to carry over methods used in one system to other cases. If they learn that it is not necessary to distinguish between mass and force (weight), they fail to make the proper distinction when using the C.G.S. system. For example, they fail to compute properly the amount of work done in lifting a body whose mass is stated in grams. It is pedagogically bad to teach two different systems in one of which a distinction between mass and force (weight) must be made and in the other a distinction is not necessary.

4. It is pedagogically bad to call the units of two entirely different concepts by the same name (pound).

5. An example of the confusion that follows the use of this system is the difference of opinion and constant confusion in the definition of such things as moment of inertia. An inspection of textbooks and handbooks shows this confusion. Many engineering handbooks fail to use the factor g in a consistent manner. For example, this factor must appear in either the expression for moment of inertia or of rotational energy, but not in both. Some err in omitting it in both, others make the mistake of using it in both expressions.

Conclusions

There is one obvious remedy for the trouble which is found among elementary students, a remedy often suggested and rarely followed. The remedy is to stop using British systems. However most teachers admit that this is impractical. Moreover, with the increasing demand that we must stress the practical applications of the principles of mechanics, it seems probable that we must use British units more than ever.

There is another remedy, one which has already been adopted in a few high school and college texts. (See Huntington, Amer. Math. Monthly XXIV, p. 1, Jan. 1917, and XXV, p. 1, Jan. 1918.) This method is based on the following experimental relation. When different forces act on the same body,

$$\frac{F_1}{a_1} = \frac{F_2}{a_2} = \frac{F_3}{a_3} \ldots = \frac{w}{g}$$

Or, in general

$$F = \frac{w}{g} a$$

This equation is taken as the fundamental equation and the others derived from it. The resulting equations are the same as those of the absolute and A systems if for m in the equations of these latter systems w/g is written. There is, however, the important difference that *mass* does not appear explicitly in any of the equations. Hence there is no necessity for any definition or unit of mass and nothing is assumed regarding any proportionality factors. When the equation $F = ma$ or $F = (1/g)ma$ is taken as the fundamental equation the resulting equations are limited to a particular set of units, but in this method no such limitation exists other than that demanded

by the ordinary rules of algebra. Practically this system is often thought of as a form of the *A* system but it is really more general. For elementary teaching it has the advantage that the concept of mass, which some regard as the most difficult of the fundamental concepts, need not be introduced early in the course. The advocates of this method suggest that it be used for all kinds of units, using but the one set of equations. However, this report is concerned primarily with those systems which are more widely used and does not attempt to discuss the merits of this different mode of approach.

The Committee has found that there is a difference of opinion as to the remedies that should be used. Some firmly believe that at least three systems, the C.G.S., the British Absolute, and a British Gravitational should be taught. Some add to this the Metric Gravitational system. But the majority, so far as the Committee has investigated, believes that it is worth while to reduce the number of systems which should be taught to a beginner.

There is also a disagreement as to whether the *A* or the *B* system is the better way to teach Engineering units. But the majority seem to favor the *A* system.

The majority of those consulted and all the members of this Committee with one exception concur in the following recommendations These are proposed not with the expectation of settling matters but from a desire to stimulate teachers to think about this problem.

Recommendations: 1. We believe that the teaching of the British Absolute system is unnecessary and that the omission of it would tend to reduce confusion.

2. We believe that preference should be given to the British Engineering *A* system rather than to the *B* system.

3. We believe that in addition to the C.G.S. Absolute system college students should be taught the British Engineering *A* system.

The Committee will be glad to receive suggestions from teachers and requests that they be sent to the chairman at 211 Hicks Avenue, Columbia, Missouri.

EDUCATIONAL COMMITTEE, AMERICAN PHYSICAL SOCIETY:

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A MODIFIED FORM OF THE TRUE-FALSE TEST.

By Howard Y. McClusky and Francis D. Curtis,
University of Michigan.

Ever since its first appearance, about seven years ago, the True-False test has been a widely used and popular measuring device. Recently, moreover, its popularity seems to be increasing with the teachers of science, particularly of general science, a fact which is indicated by the recent appearance of several standardized True-False tests in that subject.

While the True-False is doubtless a useful and valuable form of test, there has always been considerable objection to it because (1) it facilitates the "proclivity to borrow from one's neighbor,"[1] (2) it is unsatisfactory "as an instrument for diagnosing special individual difficulties,"[2] and (3) it permits more or less successful guessing of the correct response. As regards this third criticism, while Ruch states that "pure guessing (in the True-False) is comparatively rare with most individuals,"[3] some guessing, nevertheless, is generally admitted as a probability, and consequently the "guessing factor" constitutes probably the most serious objection to the True-False; for one cannot tell whether the correct response to any given True-False statement is the result of accurate knowledge or clever analysis, or of lucky guessing.

The authors have recently completed a limited investigation with a modified form of the True-False, which seems, in so far as the results may be indicative, to possess several marked advantages over the original form.

The investigation was conducted with five classes in science in the University (of Michigan) High School, one each in ninth- and seventh-grade general science, two in eighth-grade general science, and one in tenth-grade biology. A test of fifty true-false items was prepared for each class; each test was divided into two halves, each half containing the same number of true statements, but having about twice as many false as true statements. The items in the respective halves were paired as accurately as could be done subjectively with respect to type and difficulty. For each class, the entire set of statements was mime-

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[1]F. B. Knight, "Data on the True-False Test as a Device for College Examinations," *Journal of Educational Psychology*, XIII (1922), 75-80.
[2]H. M. Barthelmess, "Reply to a Criticism of Tests Requiring Alternative Response," *Journal of Educational Research*, VI (1922), 357-59.
[3]Giles M. Ruch, *The Improvement of the Written Examination* (New York: Scott, Foresman & Co., 1925) pp. 116-17.

ographed as Sheet I, and an exact duplicate of the items on Sheet I was mimeographed as Sheet II, with the exception that the items in the second half of I became those of the first half of II; thus numbers one to twenty-five on Sheet I became numbers twenty-six to fifty on Sheet II, and vice versa. Both Sheets I and II were administered to each class during a single class period.

The directions upon Sheet I were as follows:

Some of the following statements are true, and some are false. Put a letter "T" in the left margin opposite the statements you consider to be true as stated, and an "F" opposite those you consider false. Do not fail to mark all of the statements. In all cases when in doubt, guess.

Examples: 1. T Carbon dioxide is more dense than air.

2. F Carbon dioxide is more dense than water.

The directions upon Sheet II were as follows:

Some of the following statements are true and some are false. Put a letter "T" in the left margin opposite the statements you consider to be true as stated, and correct the statements you consider to be false by changing *not more* than *two* words in the original statement so as to make it true. Make all changes in the form of *substitutions*. No credit will be given for false statements which are corrected merely by the insertion of the word "Not." Do not change the subjects of any of the statements.

Examples: 1. T Carbon dioxide is more dense than air.

less

2 Carbon dioxide is ~~more~~ dense than water.

Some typical items and responses selected from the various Sheets I, follow:

1. T. An eclipse of the moon occurs only at full moon.

2. F. An inflated tire weighs less than it would if it were not inflated.

3. F. The plant seed contains the embryo and all the substances needed for its development except fat.

4. F. The response which plants make to gravitation is called phototropism.

5. F. A fireplace heats the room mostly by conduction.

Correct responses to these same items on the corresponding Sheets II, follow:

1\. T. An eclipse of the moon occurs only at full moon.

more

2\. An inflated tire weighs ~~less~~ than it would if it were not inflated.

(If allowed to change *three* words, pupils may correct this item thus:)

A deflated

2\. ~~An inflated~~ tire weighs less than it would if it were not deflated.

~~inflated.~~

3\. The plant seed contains the embryo and all the sub-

water

stances needed for its development except ~~fat.~~

light

4\. The response which plants make to ~~gravitation~~ is called phototropism, (or since this item can be made correct by substitutions in two different ways).

4\. The response which plants make to gravitation is

geotropism

called ~~phototropism.~~

radiation

5\. A fireplace heats the room mostly by ~~conduction.~~

It will be noted that the sole difference in the two test sheets is that with Sheet I, the pupil is required only to decide whether the statements are true or false, and then to mark them T or F as the case may be; but with Sheet II, he must not only decide whether the same statements are true or false, but he must analyze the false ones to detect what the false element or elements in them are, and then must substitute for the false words others which correct the inaccuracies in the original statements.

The investigation furnished evidence in support of the following conclusions:[4]

1\. *The Modified Form takes more time to administer than the True-False.* For the five classes in science, the average difference in median time was 38.2 per cent. In marking the tests, it was found, moreover, that somewhat *more time is required to score the Modified Form than the True-False*, though, after a few papers have been scored, the extra time required for the Modified Form is very little. With respect to statements which admit of more than one correct answer, it is easily practicable to make a key which indicates the acceptable alternatives.

[4]For the statistical evidence supporting these various numbered statements, see the authors' complete report of this investigation in the *Journal of Educational Research*, XII (1926) 213-24.

Occasionally, as in the Completion Form of test, though less frequently in this Modified Form of the True-False, an admissible answer is given which did not occur to the examiner in making the test; but these cases are relatively rare and their noting does not require much additional time, nor do such sporadic cases appreciably affect the objectivity of the test.

It should be stated, also, that in so far as could be judged, it takes no longer to construct items for the Modified Form than it does to make *good* statements for the Conventional True-False; and from the nature of the corrections required, the Modified Form is probably apt to contain fewer inconsequential items than the True-False. One, moreover, soon acquires the knack of constructing suitable test items for the Modified Form.

It may appear, on first thought, that the pupils themselves will not be able to score the Modified Form, but practice shows that they can score it satisfactorily. Slightly more time is required in scoring the Modified Form than is needed by them in correcting the True-False, but this added expenditure of time is amply justified through the added discussion occasioned by the effort to determine the proper answers. Further discussion gives the Modified Form a teaching value superior to that of the True-False.

2. *The Modified Form possesses a greater usefulness in homogeneous grouping for drill upon certain units of work than does the True-False.* This fact is indicated by the consistently greater standard deviations of the Modified Form. *The Modified Form, moreover, is superior to the True-False for the diagnosis of individual and class difficulties and weaknesses.* For example, occasionally a pupil changes a statement which is already correct in such a way that it is still correct, though with altered meaning; such a reaction is therefore accepted as being indicative of confusion about that particular point in the pupil's mind, and as revealing a teaching opportunity which the True-False could not bring to light.

3. *The Modified Form is a better power test than the True-False.* A number of the more able pupils actually scored several points higher in the Modified Form than in the Old Form, because, as several stated, under the necessity for more careful analysis and reasoning in the former, they discovered meanings overlooked when taking the True-False. On the other hand, the weaker pupils, almost without exception, made higher scores in the True-False.

4. *The Modified Form is more reliable than the True-False.* The reliability of the former computed from Brown's formula, was found to be .93 and of the latter, .82. The reliability of the Modified Form, moreover, compares favorably for tests in science with the reliability of the Recall and the Multiple Response tests experimented upon by Ruch.[5] The reliabilities of Ruch's Recall and Five-response tests, computed also from Brown's formula, were respectively .90 and .89.

5. *The Modified Form is more difficult for the pupils than the True-False.* The stronger pupils, however, like the Modified Form better: They enjoy the challenge of the puzzle element and the stimulus to wholesome competition offered by the Modified Form, which they think gives them a better chance to reveal what they really know. This Modified Form, moreover, since it demands a focus of attention upon content, eliminates whatever tendency there may be on the part of the more alert pupils to concentrate upon the mere mechanics and technique of wording of the statements.

6. *The Modified Form tends to eliminate whatever elements of guessing may be functioning in the True-False.* Lucky guessing seems hardly possible in a statement demanding the changing of one or two words. With the Modified Form, moreover, the "guessing factor" can be entirely eliminated by making all the statements false and by so informing the pupils at the beginning of the test.

[5]Ruch, op. cit. p. 99.

UNIVERSITY ENCOURAGES PRACTICAL STUDY OF BOTANY.

A wild-flower contest, to continue 10 years in the schools of the State, has been projected by the University of Texas with the purpose of familiarizing teachers and pupils with wild flowers of their own locality. Annual exhibits will be prepared by the schools to consist of 30 specimens, 10 each gathered in the fall, winter, and spring, pressed and mounted according to directions announced by the professor of botany of the university, who is director of the contest. The scheme contemplates preparation of exhibits in triplicate and retention of one set by participating schools. The best exhibit in each county will be sent to the university. At the expiration of the 10-year period the university will have a collection of wild flowers from different parts of the State, and each school participating will possess an exhibit of 300 authentically identified wild flowers of its locality. The process of collection is purposely made gradual in order that pupils may learn the specimens thoroughly, and that the numbers received at the university at any one time may not be too great.—*School Life.*

THE PYTHAGOREAN THEOREM.

By J. S. Georges,

The University High School, Chicago, Ill.

There are two types of pupils who demand special consideration and guidance from the teacher of elementary mathematics, the pupils who display interest in the subject, and those who take mathematics as a required subject but have developed no particular interest in it. The former type needs the inspiration and guidance into new channels of mathematical interests, and the creation of a keen desire for the acquisition of further and more extensive mathematical knowledge; while the latter must be offered a glimpse of the more pleasant aspects of the subject, which are not ordinarily included in the text. Both of these demands are met in the supplementary project work.

Classical theorems and problems offer splendid material for supplementary work, but the teacher must have an adequate acquaintance with the mathematical literature in order to refer his pupil to the exact source where such material may be found and comprehended by the pupil with facility at his stage of development. The few interesting aspects of the Pythagorean Theorem presented in this paper suggest a method of collecting and utilizing classical material for supplementary project work.

The theorem, that the square on the hypotenuse of a right triangle is equal to the sum of the squares on the other two sides, known as the Pythagorean theorem, may be regarded as the most important theorem of Euclidean geometry, or even of elementary mathematics, for it has occupied a position of unique interest in the development of all branches of elementary mathematics; and its historical significance may be realized from the fact that its truth was known by the ancient peoples long before the Greek geometers began to give a rigorous demonstration. It is also known as "Euclid I, 47," being the last theorem of Book I of Euclid's "Elements." In the middle ages it went by the name of "Magister Matheseos," and represented to the early European Universities an adequate goal in mathematical attainments; for no man could rightfully claim the title of mathematician who did not know this theorem, as some mathematicians of the present day consider the Abel's theorem. And in France and Germany the title "pons asinorum" or "the asses' bridge" was applied to it, which designation was perhaps attributed to some particular geometric construction, though in

England this term is applied to the figure of an isosceles triangle.

In elementary mathematics the theorem has the unique distinction of possessing more valid proofs than any other theorem, many of which date back thousands of years and claim the names of noted mathematicians. Though no rigorous demonstration has been as yet discovered in the writings of the ancients prior to the Greek culture, yet the truth of the special cases of the theorem, such, for example, as when the sides have the ratio 3:4:5, or when the right triangle is isosceles, was a common mathematical knowledge of all ancient peoples who have left any record of their culture either in writings or in buildings. The collections of the various proofs, and the further additions to the vast number of the different proofs are of comparatively recent times. In 1819, a collection of 32 proofs was published by Hoffmann, and in 1880 Wipper's collection contained 46 different proofs. This number was increased to 96 in 1914 by Versluys. In our own country a large number were published in the early issues of the American Mathematical Monthly. Many of these proofs are similar in either method or construction, and some are applications of other geometric theorems. A few are dissection problems. However, in spite of the fact that over one hundred different proofs have been found, the search for new proofs seems to still excite the interest of the students of geometry.[1]

Although the name of Pythagoras is associated with the theorem, the historians of mathematics do not seem to agree upon the exact connection of Pythagoras with it. All seem to be certain, however, that Pythagoras was not the first one to state the theorem. On the other hand it is possible that the first rigorous proof was due to him.[2] Since most of the discoveries of the Pythagorean School were attributed to their master, we can only conjecture as to the exact proof, or proofs, discovered by Pythagoras himself.

Crude methods of constructing right angles were employed by the Egyptians, Hindus, Chinese, and probably by other nations, long before the time of Pythagoras. In Egypt, for example, the "3-4-5 method" was used in constructing right angles. It is pointed out that the base lines of the pyramids run north and south, and east and west. Probably the north and south line was determined by astronomical observations, while the east and west line was erected by the "3-4-5 method"; for Egyptian

[1]Mathematics Teacher, December, 1925.
[2]Miller, Historical Introduction to Mathematical Literature, p. 163.

geometers, or the "rope-stretchers" as they were called, constructed a right angle upon a given line by stretching a rope, consisting of three parts in the ratio 3:4:5, around three fixed pegs or stakes.[3] The method is described in Fig. 1. ABCD is a

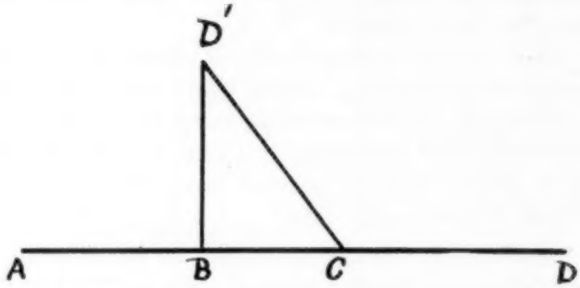

FIG. 1.

rope, with AB 4 units in length, BC 3 units, and CD 5 units. BC is placed along an oriented base line with B at the point where the right angle is to be constructed. Then the ends A and D are brought together at a point D′, so that the rope between the three points is taut. Then $\angle D'BC$ is clearly a right angle.

It is interesting to note that the method is still in use, even in this country, especially in rural districts. Usually, either the ratio 3:4:5 or 6:8:10 is used.

But other historical information also points to the fact that this special case of the Pythagorean theorem was known and used by the Egyptians. On fragments of a papyrus, claimed to be about 4000 years old, the following interesting relations have been found.[4]

$$\left(\tfrac{3}{4}\right)^2+1 = \left(\tfrac{5}{4}\right)^2,$$
$$6^2+8^2 = 10^2,$$
$$\left(\tfrac{3}{2}\right)^2+2^2 = \left(\tfrac{5}{2}\right)^2,$$
$$12^2+16^2 = 20^2$$

all of which are obtained from the relation

$$3^2+4^2 = 5^2$$

by multiplying each term by the same factor.

We have reason to believe that the "3-4-5 method" was used also by the Hindu geometers, to whom the construction of a

[3] Cajorie, A History of Mathematics, p. 10.
[4] Miller, Loc. Cit., p. 157.

right angle was a matter of religious importance, especially in connection with their altars. If the altar was to receive the sanction of the honored deity, the specified angles had to be mathematically precise. In one of the Hindu Sulba Sutras, dating back to 800 B. C., we find the statement,[5] "The diagonal of a rectangle produces what both the longer and the shorter side, each for itself, produce."

The oldest extant Chinese work of mathematical interest is an anonymous publication, called Chou-pei, written before the second century A. D., but revealing the state of the development of mathematics and astronomy in China as early as 1100 B. C. This work shows that the special cases of the theorem were known even at that early date.[6]

The isosceles right triangle attracted the attention of the early mathematicians, both as a special case of the theorem, and in its connection with the incommensurable segments, or irrational numbers. Square tiles were in use even then, and a man familiar with the consideration of areas would doubtless have recognized the truth of the theorem. For in Fig. 2 the square on the hypotenuse AB contains 4 right triangles, and is thus equal to the two squares on the sides, each of which contains 2 right triangles. Al-Khowarismi, the noted Arab author of mathematical books, gives a proof for this case. Thus this special case would have naturally raised the question of whether the relation was true in general. Pythagoras proved that it was, and the story goes that he was so jubilant over his important discovery that he sacrificed a hecatomb to the muses who inspired him.

His sacrifice was indeed well worth making if for no other reason than the proof established the first conception of irrational numbers. The concept of irrationals was perhaps one of the most dominating mathematical principles in influencing the development of geometry by the Greeks, and in lifting the subject above the plane of mensurational geometry of the Babylonians and the Egyptians. Geometry became a sublime study lifting man above sensual experiences and enabling him to transcend materialistic observations.

The Pythagorean school proved that if in an isosceles right triangle the equal sides are of a units in length, then the hypotenuse is $a\sqrt{2}$, and that $\sqrt{2}$ is incommensurable with unity. This proof given in Book X of Euclid's "Elements" is as follows:

[5]Miller, Loc. Cit., p. 159.
[6]Cajorie, Loc. Cit., p. 71.

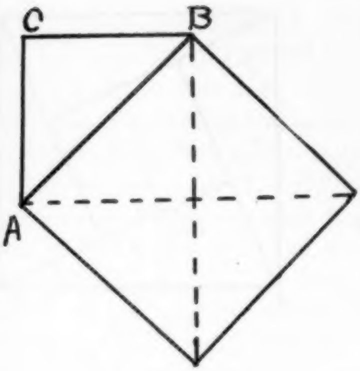

FIG. 2.

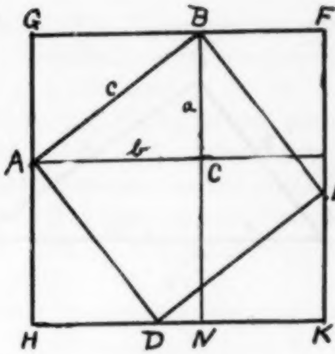

FIG. 3.

Let c and a be relatively prime integers, then since

$$c^2 = 2a^2,$$

c is an even integer. Put $c = 2p$. Then

$$2p^2 = a^2,$$

that is, a is also even, which is impossible since a is relatively prime to c. Thus a and c are imcommensurable, that is, the ratio of c to a is not a rational number.

Of the many proofs for the general case of the theorem it is not known definitely which one originated with Pythagoras. By many it is believed that the well known proof given by Euclid is not due to him but to Pythagoras. However, the demonstration of Fig. 3 is usually attributed to Pythagoras. In Fig. 3, ABDE is a square on the hypotenuse c of the right triangle ABC, and FGHK is a square on the segment $a+b$. Then it follows at once that

$$c^2+2ab = a^2+b^2+2ab,$$

or that $c^2 = a^2+b^2$.

The theorem is easily proved by means of proportion. We reproduce Legendre's proof in Fig. 4. From Fig. 4, ABC is a right triangle, and CD is drawn perpendicular, to the hypotenuse AB. From the similarity of triangles, we have

$$\frac{l}{b} = \frac{b}{c}, \text{ or } b^2 = lc,$$

$$\frac{m}{a} = \frac{a}{c}, \text{ or } a^2 = mc,$$

and adding, we get

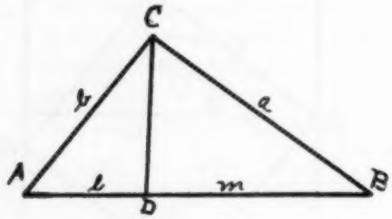

Fig. 4

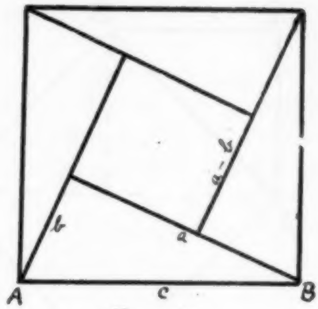

Fig. 5.

$$a^2+b^2 = c^2.$$

Bezout and others using the same figure but considering areas give different proofs.

The proof in connection with Fig. 5 is due to Bhaskara, reproduced by Hutton (Tracts, London, 1812) taken from Bija Ganita. His proof consisted of a single word "behold." The explanation which he requires his readers to see is as follows:

$$c^2 = 2ab+(a-b)^2 = a^2+b^2.$$

The figure is commonly called the "bride's chair."

The Pythagorean theorem is a special case of many geometric theorems of which we give three in connection with Figs. 6, 7, and 8 respectively.

The theorem of Ptolemy: If ABCD is any cyclic quadrilateral (Fig. 6), then AD.BC+AC.BD = AB.CD. If the quadrilateral be a rectangle, whose sides are a and b, and diagonal c, then $c^2 = a^2+b^2$.

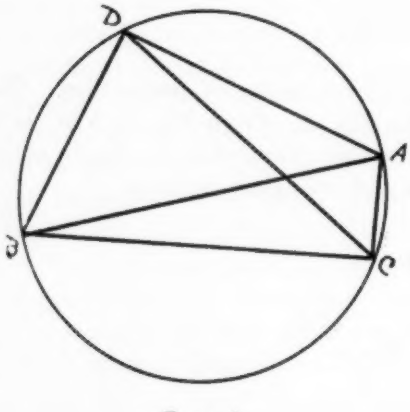

Fig. 6.

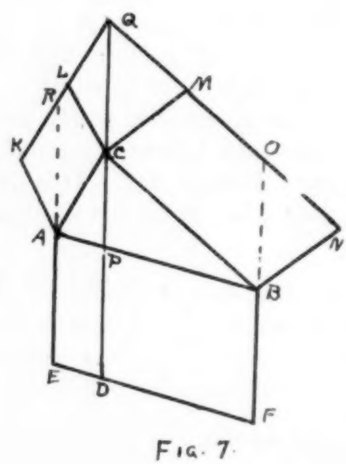

Fig. 7

The theorem of Pappus: Let ABC (Fig. 7) be any triangle, and let AKLC and CMNB be any parallelograms, constructed on AC and CB outward. Let KL and MN meet in Q. On AB construct the parallelogram AEFB, having AE equal and parallel to QC. Produce QC to intersect AB and EF in the points P and D respectively. Let BF and MN intersect in the point O, and AE and KL in the point R. Then it is easily proved that the parallelogram AF is equal to the sum of the parallelograms CN and KC.

Now if the angle C of the triangle is a right angle, and the parallelograms on AC and BC are squares, then that on AB is likewise a square, and we have the relation of the theorem of Pythagoras. The proof given in Euclid's "Elements" is clearly a special case of this theorem. Leonardo da Vinci, Wheeler, and others have given demonstrations based on the theorem of Pappus.

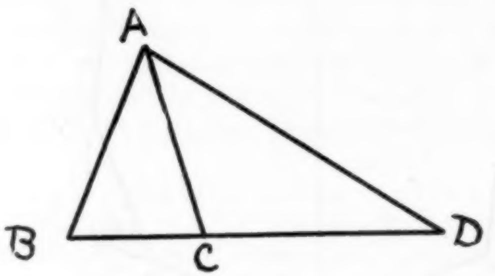

FIG. 8.

Theorem: If AC is the bisector of the vertex angle of the triangle BAD (Fig. 8), then AB.AD = AC^2+BC.CD. If the triangle BAD is isosceles, we have $c^2 = a^2+b^2$.

The last three demonstrations clearly indicate that the Pythagorean theorem admits of generalizations. Since any triangle may be considered as the sum or the difference of two right triangles, according as the triangle is acute or obtuse, the properties of a right triangle may be extended to those of any triangle. For example, if we show that the sum of the angles of a right triangle is a straight angle, we may readily prove that the same is true for any triangle; or if the area of a right triangle can be shown to be equal to one half the product of the two sides including the right angle, the same formula may be proved to

hold for any triangle. The relation $c^2 = a^2+b^2$ between the three sides of a right triangle generalizes into the relation $c^2 = a^2+b^2-2ab\cos C$ of which the former is a special case, when angle C is a right angle. Furthermore, the latter relation may be generalized to hold for any n-gon, and we have the relation $a_1^2 = a_2^2+a_3^2+a_4^2+ \ldots +2a_2a_3\cos\alpha_{23}+2a_2a_4\cos\alpha_{24}+ \ldots$ where $a_i (i = 1, 2, \ldots, n)$ are the sides, and α_{ij} the exterior angle between the sides a_i and a_j. For let $A_1A_2 \ldots A_n$ (Fig. 9) be any n-gon, and let A_1 be at the origin. Then projecting along the x-axis,

(1) $-a_1\cos\beta_1 = a_2\cos\beta_2+a_3\cos\beta_3+a_4\cos\beta_4+ \ldots\ldots$

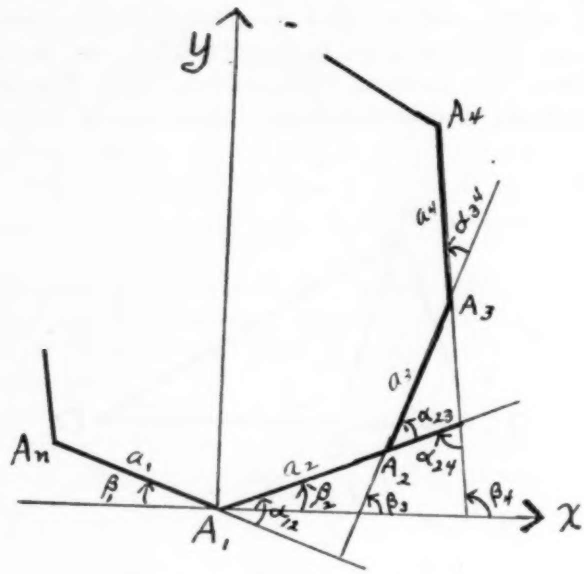

FIG. 9.

Projecting along the y-axis.

(2) $a_1\sin\beta_1 = a_2\sin\beta_2+a_3\sin\beta_3+a_4\sin\beta_4+ \ldots$

Squaring equations (1) and (2) and adding, we get

$$a_1^2 = a_2^2+a_3^2+a_4^2+ \ldots$$
$$+2a_2a_3(\cos\beta_2\cos\beta_3+\sin\beta_2\sin\beta_3)$$
$$+2a_2a_4(\cos\beta_2\cos\beta_4+ \sin\beta_2\sin\beta_4)$$
$$+2a_3a_4(\cos\beta_3\cos\beta_4+ \sin\beta_3\sin\beta_4)+ \ldots = a_2^2+a_3^2$$
$$+a_4^2+ \ldots$$
$$+2a_2a_3\cos(\beta_3-\beta_2)+2a_2a_4\cos(\beta_4-\beta_2)+2a_3a_4\cos(\beta_4-\beta_3)+$$
$$\ldots = a_2^2+a_3^2+a_4^2+ \ldots$$
$$+2a_2a_3\cos\alpha_{23}+2a_2a_4\cos\alpha_{24}+2a_3a_4\cos\alpha_{34}+ \ldots$$

But the most important generalization of the Pythagorean theorem is in connection with the integral solutions of the Diaphantine equation $x^2+y^2 = z^2$. The Pythagorean School believed that an arithmetical fact had its analogue in geometry, and vice versa. Their arithmetical theory was based not on algebraic but on geometric concepts. A number was represented by the length of a line segment, and thus in connection with the Pythagorean theorem they studied the special Diaphantine equation and devised a rule by means of which integral solutions of the equation could be found. The positive integers satisfying this equation are called Pythagorean triads. It should be noted that among the writings of the Egyptians, as well as the Hindus and Chinese, such triads as 3, 4, 5; 5, 12, 13; 7, 24, 25; etc., are found.

Pythagoras is said to have known that a triangle whose sides had the length $2n+1$, $2n^2+2n$, and $2n^2+2n+1$ was a right triangle. But this, of course, applies only to the case when the hypotenuse differs from one of the sides by unity. By giving n integral values we can find an infinite number of right triangles or number triads satisfying the Diaphantine equation $x^2+y^2=z^2$.

The formula of Pythagoras may be simplified as follows: Take for one side any odd number m, then $\frac{m^2-1}{2}$ and $\frac{m^2+1}{2}$ represent the other two sides. For since $2n+1$ is odd, put $m = 2n+1$, then

$$2n^2+2n = \frac{(2n+1)^2-1}{2} = \frac{m^2-1}{2},$$

and

$$2n^2+2n+1 = \frac{(2n+1)^2+1}{2} = \frac{m^2+1}{2}.$$

Thus we have such triads as 3, 4, 5; 5, 12, 13; 7, 24, 25; 9, 40, 41; 11, 60, 61; etc.

According to Proclus the following rule was obtained by Plato: If $2n$ is one side, then n^2-1 and n^2+1 are the other two sides. Since $2n$ is even, we may take for the triads given by this rule, m, $\frac{m^2}{4} - 1$, and $\frac{m^2}{4} + 1$, where m is any even number greater than 2, such, for example, as the triads 4, 3, 5; 6, 8, 10; 8, 15, 17; 10, 24, 26; 12, 35, 37; etc.

Note that the first triad is again 3, 4, 5, and that the second is twice the first with the numbers 3 and 4 interchanged. Again Plato's triad 10, 24, 26 is the same as Pythagoras' 5, 12, 13. But Plato's rule gives such triads as 8, 15, 17 and 12, 35, 37, which are not given by Pythagoras' formula. Conversely, Plato's formula does not give the triad 7, 24, 25 given by Pythagoras', though for $m = 14$, Plato's rule gives the double of each number of the triad.

It may easily be shown that Plato's triads are more general than those of Pythagoras, for the latter are included among the former as special cases. For if we put $m = 2(2n+1)$, then we get the triad $2(2n+1)$, $2(2n^2+2n)$, and $2(2n^2+2n+1)$ which is that of Pythagoras doubled.

In considering the general case, we note that three facts are necessary for the complete determination of a triangle. Since the triangle is a right triangle, two further facts are required, and we should expect to have two unknowns in the general formula. Plato's formula does not contain two unknowns, hence it cannot be the general formula. In fact it does not give the triad 20, 21, 29.

To find all the solution of the equation

(3) $\quad x^2+y^2 = z^2,$

it is only necessary to find the primitive solutions, that is when x, y, and z have no common factors, since every non-primitive solution may be found from a primitive one by multiplying the three numbers x, y, and z by the same factor. Thus the triads 3, 4, 5 and 6, 8, 10 as well as the triad $3/4$, 1, 5/4, if we consider positive rational solutions also, will be regarded as the same solution.

Now in order to obtain primitive solutions of equation (3), x, y, and z must not have a common factor. Then the following three cases are to be considered: (1) x and y both even; (2) x and y both odd; (3) either x or y odd, and the other even.

If x and y are both even, then equation (3) shows that z would have to be even also. But z cannot be even to give primitive solutions. Thus case (1) is excluded.

Next, if x and y are both odd, then x^2 and y^2 must each be of the form $4k+1$ and the sum x^2+y^2, i. e., z^2 is of the form $4k+2$. But $4k+2$ is not a square. Thus case (2) is also excluded since the sum of two odd squares is not a square.

So the third alternative is left, and either x or y is odd and the other even. Let x be even, then x^2 is of the form $4k$, and y^2

of the form $4k+1$. Hence z is also odd. Write

(4) $x^2 = (z+y)\,(z-y).$

Then, since y and z are both odd,

$$\begin{aligned} z+y &= 2k,\\ z-y &= 2l, \qquad (5)\\ x^2 &= 4kl. \end{aligned}$$

Now if y and z had a common factor, x would have that factor also. For if

$$z = am,\ y = an,$$

then

$$z+y = a(m+n),\ z-y = a(m-n),$$

and

$$x^2 = a^2(m^2-n^2).$$

Thus y and z must be relatively prime, and $z+y$ and $z-y$ can have at most the common factor 2. Hence from the first two relations (5) k and l are relatively prime, and from the last relation (5) k and l each must be a square. We therefore write

$$\begin{aligned} z+y &= 2p^2,\\ z-y &= 2q^2. \end{aligned} \qquad (6)$$

Relations (6) and (3) give

$$\begin{aligned} x &= 2pq,\\ y &= p^2-q^2, \qquad (7)\\ z &= p^2+q^2. \end{aligned}$$

All the primitive solutions are given by (7). Furthermore, p and q are relatively prime, for otherwise x, y, and z would have a common factor and the solution would not be primitive. And since y and z are both odd, p and q cannot be both odd or both even. And in order for the second relation (7) to have a meaning, p must be greater than q. Tables giving the primitive solutions up to certain numbers have been constructed. For example see Whitworth's Tables in Proc. Lit. and Phil. Soc. of Liverpool, vol. XXIX, 1874, p. 237.

Since all the integral solutions of the equation have been found, one might naturally expect to have similar success with the equation $x^3+y^3 = z^3$, or even the general equation $x^n+y^n = z^n$. But as early as the 17th century the great mathematician, Fermat, stated that this equation cannot have positive integral or positive rational solutions. His proof for $n = 3$ is lost, but Euler has supplied one. Fermat's proof for $n = 4$ is extant. In announcing his important theorem Fermat stated that he did not furnish the proof because of the lack of space on the margin

of his copy of a work by Diaphantus. Since then such eminent mathematicians as Euler, Dirichlet, Legendre, Kummer, and others have tried to furnish the proof, but without success. Proofs have been found for various special values of n, including every value of $n < 100$, but the proof of the general case is still a challenge to the mathematical world. Both mathematical distinction and a large prize await him who is able to furnish a general proof, or can show in one instance where the theorem fails, before the year 2007 A. D.

EARTH SYSTOLE AND DIASTOLE.

The startling suggestion that the earth cannot be relied upon to stay the same size but that it swells and shrinks at irregular intervals is made by Dr. Walter D. Lambert of the United States Coast and Geodetic Survey. Such a variation in the size of the earth would alter its rate of rotation and so upset our universal time-piece, for the length of day is our measure of the lapse of time. Prof. E. W. Brown has pointed out that such a variation in our unit of time might account for the apparent irregularities in the motion of the moon that have made it impossible to predict exactly where our inconsistent satellite will turn up at an eclipse. Dr. Lambert thinks it may also account for inexplicable variations in latitude, or what is the same thing, the apparent wandering of the pole. For some years prior to 1918 the north pole appears to have moved progressively toward North America and then to have turned aside without apparent reason and moved toward Europe. Comparatively slight expansions, and contractions of various parts of the earth's surface might account for such disconcerting discrepancies in our standards of time and space.—*Science News-Letter.*

SUMMER SCHOOL COURSES IN MATHEMATICS AT THE UNIVERSITY OF CHICAGO.

First term, June 20 to July 27; second term, July 27 to September 2. In addition to the usual courses in college algebra, plane analytical geometry and differential and integral calculus, the following advanced courses are announced: By Professor G. A. Bliss: Calculus of variations; Thesis work in analysis. By Professor H. E. Slaught: Differential equations; Theory of definite integrals. By Professor E. T. Bell: Theory of functions of a complex variable; Theory of modular systems; Reading and research in the theory of numbers. By Professor H. H. Mitchell: Introduction to higher algebra; Analytic theory of numbers; Reading and research in algebra and the theory of numbers. By Professor W. C. Graustein: Analytic projective geometry; Metric differential geometry; Reading and research in differential geometry. By Professor Mayme I. Logsdon: Differential calculus; Algebraic geometry of hyperspaces; Reading and research in algebraic geometry. By Professor Warren Weaver: Electro-dynamics; Integral calculus; Reading and research in electro-dynamics. By Dr. Walter Bartky: Celestial mechanics; Descriptive astronomy.

THE EVOLUTION OF INDUSTRY AS RELATED TO THE EVOLUTION OF SCIENTIFIC KNOWLEDGE.

By R. E. Rose,

Director, Technical Laboratory, E. I. du Pont de Nemours & Co., Wilmington, Del.

I am an industrialist; I was a teacher. Because of this I feel that I may be able to interest you in my discourse by connecting the industries of this Country, the foremost of all industrial communities, with the underlying knowledge necessary for their growth, this knowledge having been secured by those who are in the highest sense the teachers of mankind, those all-important men who, possessing genius, show us how to control natural forces. We can agree, I think, that the research worker advances our knowledge by gaining a power over the material with which he works and in that way makes it yield to his wish to know. Whether he is a chemist, physicist, biologist, astronomer or engineer, the essence of his success is the same. He learns better than others to understand the cause of effects and hence becomes able to produce those effects under quantitative control, whereas before, all that was known of them, if they were known at all, was that they occurred under certain conditions prescribed by rule of thumb. Many times his success means no more than deeper insight into our surroundings. It then remains what we call pure research. Sometimes it lends itself to the growth of an industry because of its great value to the generality of mankind. In that case it becomes linked with what we call industrial research which is essentially an effort to make knowledge, already acquired, productive under industrial conditions.

How best to bring the facts to your attention has puzzled me not a little. Were I to treat the subject historically I would but restate what is known to all of us. I would go back once more to the cave man and trace his evolution. I feel we have had enough of this because we spend so much time in the early history of science that we do not, in a sense, reach the present day at all. On this account my decision has been to approach the subject from the present. I would then draw your attention to the great industries which we are fortunate in possessing, industries that clearly make our material civilization what it is. Then I would go back and connect these industries with the knowledge that lies behind them, with the knowledge that alone makes them possible, and show you how the laboratory of the

scientist is really the seed bed from which have come all our great enterprises.

The simplest way to secure a representative list of industries is to take those whose stocks are traded in on the New York Exchange. In this way we obtain a representative section through the whole commercial life of the Country. The companies whose stocks are traded in are almost without exception new. They are the growth of a generation, with the exception of our transportation systems and some of the mining and metallurgical corporations. This is the first fact that strikes one when one looks at them from our present point of interest. Furthermore, the majority of them are not merely new as business organizations. They are actually active in lines of industry which are fundamentally new.

For our purpose it is better to effect some kind of classification of the corporations on the basis of the research underlying their activities. We may do this roughly in the following way:

A. Companies dealing with the production of energy either as such or as material convertible into energy. Companies dealing with energy transmission for special purposes. This group would comprise such well-known corporations as the General Electric, the Westinghouse Electric, the American Telephone and Telegraph, the large electric power companies such as the group of Edison Public Utility Corporations, but it would also include by definition the coal mining companies, the petroleum companies and the gas companies.

B. Transportation companies. This group would include all the railroads and street railroads and the bus lines. It would really be that group which sells energy converted into motion.

C. Chemical industries, that is, those corporations whose primary object is the conversion of one kind of matter into another. In this group we find the Allied Chemical & Dye, Commercial Solvents, Du Pont Company, Mathison Alkali, and Union Carbide and Carbon, the Rayon companies, Explosive companies, etc.

D. The mining industries, other than coal.

E. The metallurgical industries such as United States Steel and the other smaller steel companies. The large copper producers such as American Smelting and Refining, Anaconda, Kennecott.

F. The fabricating industries, those which assemble material

and turn it out in a different mechanical form. Under this head I propose to include the railway equipment companies such as Baldwin Locomotive Works and the American Locomotive, the automobile manufacturers and the host of other concerns who make furniture and build bridges and edifices of all kinds. The textile industry, the paper industry, and so on, are included here.

G. The distributing industries, the wholesalers and retailers of all kinds who are merchants and not producers such as the chain stores, the mail order houses and the thousands of department stores and shops all over the Country. These are represented in the list of stocks by such companies as Armour, S. S. Kresge, Woolworth, Gimbel Brothers, May Department Stores.

Such a classification, rough as it is, will serve our purpose but I warn you that it is so rough that frequently a large industrial unit may be functioning in two or even more of the classes.

Every thinking man must appreciate that all these industries represent an intensity which was quite unknown until the beginning of the 19th century. It is also clear that this development is a direct consequence of the fact that man learned to secure sources of energy other than his own. It is right then that we should start our inquiry with the industries which furnish the basic energy of the Country. Now the point I wish to make is that these companies are possible not simply because man realized that he wanted more energy than his body would produce, but because of the building up of a mass of accurate knowledge which allowed of the utilization of natural forces and without which such utilization would have been impossible. The part played by knowledge in the development of modern life is exceedingly well summarized in a sentence by Lord Balfour, the English philosopher and politician—"Science is the great instrument of social change, all the greater because its object is not change but knowledge, and its silent appropriation of this dominant function, amid the din of political and religious strife, is the most vital of all the revolutions which have marked the development of modern civilization."

The most obvious form of energy available was water power but until this was converted into electricity it was used only to a limited extent in flour milling and similar processes. The reason was simply that this source of power is available only at certain places and cannot be transmitted to a distance. More-

over, to utilize it, meant machinery that required developments made only recently. Fire was quite obviously a form of energy which might be used and the records show that the Greeks were already ingenious enough to make use of it to produce mechanical effects. Hero, of Alexandria, invented a mechanism for opening and closing the doors of a temple, apparently of their own accord during religious services, which depended on the fact that an air space under the altar was heated by the altar fire; the expanding air displaced water which threw a weight and moved the doors. When the fire was extinguished the air contracted and the reverse process occurred.

The knowledge necessary to the modern development of power was acquired largely during the 17th century when a group of extra-ordinarily brilliant investigators came together and put into effect methods of research which had already been proposed by Roger Bacon and Francis Bacon, Lord Verulam. Essentially this age saw the transition from qualitative to quantitative investigation. In consequence of this we learned enough of the character of the air as an elastic fluid to make it possible for Savery, in 1770, to invent the first working steam engine. This, like Newcomen's, depended on the fact that steam would displace air and that condensation of the steam resulted in the formation of a vacuum making possible the use of the pressure of the atmosphere. Soon afterwards Watt followed with an engine very similar to the type in use at present. We can say that 1770 saw the start of all our industrial organization and that it was a consequence of the study of gases carried out 100 years previously. Does not the student of physics and chemistry still labor in an effort to remember the meaning of the law of Boyle relating to the behavior of gases under pressure?

The coming of the steam engine made possible the development of energy from coal for the running of machines. It did not give rise to power companies in our modern sense because the transmission of steam over any great distance is accompanied by such heavy losses that it is not practical to generate it in a central station for the use of a whole industrial community. However, each factory generated its own steam power just as did the mines who used the first engines for pumping water from their shafts. It is well to remember that this first and exceedingly important development was consequent upon the possibility of grasping mentally the physical attributes of a gas and

that the theoretical conceptions, although important and indeed necessary, were comparatively simple in contrast to those required for the next development of power which was that of electrical energy.

It is good for us to look back now and then in order to appreciate what modern knowledge has done in changing our destiny and I do not think that there is any more astonishing fact than this: that the generation of electric power which is now a major industry was first carried out on a practical scale in 1873. What are the scientific discoveries underlying this tremendous development? We find that William Gilbert, at the end of the 16th century, carried out the first quantitative investigation of the phenomena of electrification. In 1770 Galvani made the celebrated discovery of the effect of an electric machine of the friction type on the legs of frogs. Volta investigated this phehomenon and made the great discovery that bodies differed in their el ectric charges. This led him to the building of the Voltaic pile which was the first instrument for producing an electric current.

Faraday, in 1821, found that a wire conveying a Voltaic current could be caused to rotate around the pole of a permanent magnet. Afterwards, in 1831, he discovered the phenomenon of electro-magnetic induction. This was in answer to the question which he had asked of himself, whether, since one conductor was able to produce a charge of the opposite sign in a neighboring conductor, it might not be possible for an electric current passing through a conductor to generate a current in a neighboring conductor. It took him six years to obtain a successful experiment but once he had reached his method his investigations proceeded with astonishing rapidity because he was already mentally quite clear as to the nature of the phenomena he was studying. It took him but ten days to lay the foundations for the whole of the basic knowledge required for the production of electricity by dynamos, that is, the conversion of mechanical into electrical energy.

Very naturally the fact that a disk of copper rotating in an electric field produced a current was taken up by those who were less profound scientists than Faraday but who were of an inventive genius. They soon turned out rough dynamos which were quite serviceable. In 1870 Gramme produced a new type which led to the fundamental discovery that a

dynamo could function as a motor if a current were run through it. That discovery, made in Vienna, was the start of all the companies which deal with the conversion of the energy of water power or of coal into electric energy. Just how many millions are invested in the production of electrical energy I am not able to say—figures of this sort are usually wearisome—but the immensity of the operations is apparent. In 1925 the people of this Country paid $122,373,000 monthly to the electric power companies.

Electrical energy differs from mechanical in being a form that is entirely distinct from any function of the body or of any mechanism worked by the body. It really presented an entirely new tool to man's inventive genius. It is not surprising that it was used in a great diversity of ways. The first practical outcome was telegraphy in 1844 which depended on the discovery of Oersted that a magnetic needle was deflected if a current passed through a conductor in its vicinity. This work was amplified by the profound researches of Lord Kelvin, and the great cable companies stand as a memorial to his scientific ability. What this has meant in making easy the transaction of business necessary to industry is more than we can estimate. I heard recently of an order for the sale of cotton on an American Exchange which left Liverpool, was executed, and the confirmation received back in Liverpool, all in 2½ minutes.

Telephony was another outcome which we can trace directly to the work of Volta and Oersted in the hands of Alexander Graham Bell. Both these developments required comparatively small quantities of electrical energy and therefore did not have to wait upon the perfection of the dynamo. The telephone is an instrument that has modified both private and business life. In this Country last year the daily average of local 'phone calls was nearly seventy million. Granting that a great many of these were a pure waste of time, yet the effect on our intercourse is quite obvious. Toll calls of which the percentage in the interest of business is probably higher than of local calls, run to 2,500,000 daily and are increasing so rapidly that by 1930 an estimate of 1,002,000,000 is that which has been made by the Bell Telephone Company. Of the Bell System itself we may say that it is one of the most efficient and one of the largest corporations we have. The operating expenses for 1925 amounted to the extraordinary total of $508,000,000 dollars. The American Telephone and Telegraph, operating this gigantic system,

spends more money than any other corporation on real research. That is one of the chief reasons for their success.

The conversion of electrical energy into light is the next story connected with our industrial corporations. Ohm studied the nature of electromotive forces and improved our knowledge of the effect of electricity acting through resistances. Davey made the first electric lamp which was really a carbon arc but naturally, with the very small available supply of electrical energy, it was merely a curiosity. The perfected arc represented an enormous advance over any older form of illumination. Its intensity was greater, it could be placed more advantageously, so that the lighting of railroad yards and street intersections became possible with far greater effect than before. It had a great many disadvantages. It was noisy and erratic and required constant attention. But the incandescent type lamp developed along with the arc Edison's attention was directed to the problem of constructing a lamp with glowing filament. The most refractory metal available, platinum, melted so little above the temperature at which it began to glow and was, moreover, even in those days, so costly that the use of a metal was out of the question. It was only when Edison devised a method for making carbon filaments from organic matter by dipping and burning that the incandescent lamp became at all practical.

To use incandescence it was necessary to have a source of electrical energy more lasting than the dry cell and Edison started the first power house in Pearl Street, New York City, in 1886, supplying his customers with electric current for his incandescent globes. The development of the incandescent made possible the introduction of electric lighting in the home and started us on our road to independence from sunlight.

We can afford to follow the history of the development of electric lighting a little further because it illustrates admirably how knowledge lends itself to current industrial exploitation. The carbon lamp does not have a very high efficiency, that is, a great deal of the electric current is converted into heat instead of light. Even so, it was a very great advance. The hunt for other filaments, some of which might be expected to give better efficiency, was continued and in consequence of our growing knowledge of the rare metals, tantalum was used. Tantalum

is distinctly better than carbon and it seemed to be a metal which would be used for some time to come when things were altered by a discovery made in this Country by Dr. Coolidge, of the General Electric Company. Tungsten should be very well suited to the production of light electrically because it has an extremely high melting point, 3350°C. However, things do not fall out as nicely as one might hope and in every case, practically, we find very great difficulties in achieving commercial results from what seems a simple starting point. The trouble in this case was that tungsten refused to be drawn and, therefore, the making of filaments was a practical impossibility. All sorts of variations were tried, low temperatures, high temperatures, different types of mechanical treatment, but in every case a brittle, useless wire resulted. Coolidge was able to show that if the tungsten was purified very thoroughly it became a very ductile metal, provided it was treated by a method just opposite to that which would be used in the case of other metallic substances. An ordinary metal, when heated above its annealing point and then cooled slowly, becomes soft. Tungsten, under these circumstances, becomes brittle. The only way of making it ductile is to crush it while it is cool which is accomplished by heating to a temperature below its annealing point and then working repeatedly, each repetition being at a temperature lower than the preceding. When treated in this way the tensile strength is astonishing, being 600,000 pounds per square inch for wire one-thousandth of an inch in diameter. This was the necessary preliminary work to the revolution in electric lighting represented by the tungsten filament. It is not very many years since the introduction of this variation in lighting and yet it has really given us a light intensity comparable with that of daylight for all ordinary purposes, at a cost less than that of the poorer light obtained from the carbon filament. In home and workshop, in street car or in the department stores everything is flooded with light during all working hours, whenever it is needed, a brilliant white light that enables the worker to carry out the most delicate operations with no more eye strain than he would have if working in sunlight.

The tungsten lamp in this form did not mark the last stage in the development of incandescent lamps, though the tungsten filament doubled their efficiency over carbon lamps, that is to say, it doubled the percentage of electrical energy converted into light energy. Dr. Langmuir, whose researches on the structure of the

atom seemed about as far from practical application as any research could well be, succeeded in improving the light. He did this by devoting himself exclusively to the fundamental character of the changes taking place in the bulb and paying no attention whatsoever to the practical meaning of his results. The defects of the tungsten lamp were that it blackened rather rapidly and therefore the light emitted decreased in direct proportion. It was possible to trace this blackening to a continuous process caused by the minute quantities of water vapor in the bulb, which, coming in contact with the hot tungsten, oxidized it and liberated atomic hydrogen. The oxide, being more volatile than the metal, was driven onto the glass. There the active hydrogen robbed it of its oxygen, leaving black metallic tungsten and regenerating the water necessary to continue the cycle. Learning this led to further experiments and it was found that the tungsten wire, in the absence of water, lasted much longer if in the presence of a gas. However, the gas conducted away heat and therefore lowered the lighting efficiency of the wire. When an inert gas, such as nitrogen or argon, was used in the bulb the rate of filament evaporation was cut to about 1% of what it was in a vacuum at the same temperature. The minute quantity of nitride which was formed was carried to the top of the lamp by the convection currents and did not interfere with the light emission. The loss in heat was overcome by running at a higher temperature which gave a whiter light, or using a large filament. These researches helped to establish the General Electric in its dominance of the field of electric lighting but they also made available for use a very much greater amount of electric light from the same amount of energy; or in other words, since energy is the cost factor, it lowered the cost of lighting to the people of the Country enormously. Another development is the conversion of electric energy into light—an outcome of the work done by William Crooks. It was he who made a study of the characteristics of electric discharges in rarified gases and now the street signs in a great many cities, vivid scarlet and blue designs or letters glowing by night, are nothing but specially adapted Crooks tubes in which the electric discharge is caused to create the luminosity of the gas atoms. These atoms are those of the rare gases of the atmosphere made available commercially by another extension of our knowledge of the mechanics of gases, the work of Cailletet, Dewar, Linde and others, for it is these men who showed us that it was possible to liquefy air, and

liquid air can be distilled and divided into its component parts just as we can distill a mixture of alcohol and water. Argon is thus made a material available to industry since it occurs in air to the extent of about 1%.

So far the reversal of the process for the development of electrical energy, that is, the use of electricity to produce heat, has not been developed very far if we consider general use. It is true that we have the electrically heated range, the toaster and other household implements, but the actual heating of houses is not yet economical at the cost of electrical energy. We shall return to this subject, however, in considering the chemical industries which utilize heat from an electric source to produce some of their most important products. The conversion of electrical into chemical energy first realized by Humphrey Davey when he discovered sodium, potassium and magnesium, is a function of the chemical industry rather than of the power company and I propose to mention it under that heading.

The conversion of electrical energy into electro-magnetic waves, originally the outcome of a profound series of researches carried out by Hertz, has, in the hands of Marconi and a number of other inventors, given us our most novel method of communication by radio messages and developed a new industry, making radio equipment. And here in this connection I should like to draw your attention to the necessity of special instruments in converting scientific work to practical uses. The scientist who discovers a phenomenon is no more valuable from the practical man's point of view than the discoverer of the less spectacular feature, the means of measuring quantitatively that which has been discovered. Electricity, without the galvanometer, the ammeter, voltmeter, and the dozens of other control devices would be useless and in the case of electro-magnetic radiation those who have taught us how to catch and measure these impulses are just as much entitled to our credit as those who discovered the underlying phenomena. There are, I am sure, a great many who have not come across the very striking analogy given by Dr. Whitney, the General Director of the Chemical Research of the General Electric Company, to show how extraordinarily sensitive the detecting device of a radio apparatus actually is. When he listens to his receiving set in Schenectady and the message comes from the broadcasting station in San Francisco he is picking up the extraordinarily small quantity

of energy reaching his antennae. How small that quantity is he set himself to calculate. His humorous way of bringing the fact to us is to state that a fly dropping back one inch on a window pane releases enough kinetic energy to run his radio constantly day and night for 35 years.

(To be continued)

HELIUM SHORTAGE EXISTS.

America faces a helium shortage. And helium is the unburnable gas that, although undiscovered on earth before 1895, is used to inflate dirigibles and thus keep them from exploding as those filled with hydrogen are likely to do.

The natural gas from the Petrolia, Tex., field which has provided helium up until now is playing out. Since Congress has authorized the construction of two giant dirigibles, each 6,000,000 cubic feet capacity, to cost $8,000,000, lack of helium is worrying government officials. The Navy and the U. S. Bureau of Mines are asking Congress to appropriate money to pipe to the Fort Worth, Tex., helium extraction plant, built during the war, the helium-bearing natural gas of Nocona, only 25 miles from Petrolia.

The appropriation desired is $500,000 which is needed to construct the necessary pipeline and pressure plant. The bill is now awaiting action by the Senate. Once the money is appropriated it will be a matter of only six or seven months before the helium supply can be increased.

The Nocona field was discovered in 1922 but natural gas, although burned in the field, has never been drawn away. The life of the Nocona supply is about 15 years and it will probably produce from 10 to 12 million cubic feet of helium a year during that time.

More helium is essential with the construction of two giant dirigibles in view. There was never enough helium to float the Los Angeles and the Shenandoah simultaneously. With the destruction of the Shenandoah the world's largest single store of pure helium was lost. Each of the projected giant dirigibles will need three times the helium now being used by the dirigible Los Angeles.—*Science News-Letter.*

"UNITED STATES SCHOOLS" IN SOUTH AMERICA.

A school in Argentina and one in Brazil have recently been named for the United States as an expression of friendship toward this country. Impressive ceremonies attended the naming of the "United States School" in Rio de Janeiro. Addresses were made by the American ambassador and by prominent educational officials of Brazil. American and Brazilian songs and exercises were given by the children, and portraits of Washington, Lincoln, and Horace Mann were unveiled.

Children in the school named for the United States in Buenos Aires observed our American Fourth of July. The program included singing of the national anthems of Argentina and of the United States, recitations on the national flags of the two countries, and an address on the significance of the Fourth of July.—*School Life.*

THE USE OF THE SLIDE RULE IN MERCANTILE ESTABLISHMENTS.

BY ZENA BROWN.

Many high school teachers of mathematics, physics or chemistry, who are well acquainted with the application of the slide rule to their own subjects and who acknowledge its importance to a student who intends to enter an engineering college, are not at all certain of its value in the business field.

Such teachers are generally very much interested in learning about the actual use of the slide rule in office practice, as they feel that the time spent on its instruction in the class-room is justified only if it serves those students who will accept a clerical position in the business world, as well as those who plan to go on into college.

In order to give those teachers who have not had an opportunity of visiting the large commercial organizations, a good picture of how the slide rule is put to practical use, a number of typical problems encountered in large railroad offices, manufacturing industries, packing houses, and public utilities in New York and Chicago, will be submitted. The sizes of slide rules which were used in the actual solution of these problems in each case are designated, whether it be 10 in., 20 in., or the Thacher Calculator. The latter is merely a cylindrical slide rule, which is equivalent in accuracy to a 30 ft. rule and is capable of being read to five significant figures.

The scales on the slide rule are so-called "Logarithmic" scales. The reader, although he may never have used the slide rule, should readily appreciate its value in solving proportions when it is explained that adjacent locations of identical logarithmic scales are always proportionate. Thus, if figure 1 on the upper scale is placed over figure 2 on the lower one, 2 is over 4, 3 is over 6, 4 is over 8, 5 is over 10, etc. This feature of the slide rule makes it invaluable in cost accounting and railroad offices, where it is often referred to as the "Prorate Machine." In large industrial corporations, such as the United States Gypsum Co., Standard Oil Co., American Steel and Wire Co., Carson Pirie Scott & Co., etc., the Thacher Calculator is intensively used for the allocation of costs over various departments or articles of manufacture. A large number of Thacher Slide Rules are used in Freight Claim and Passenger Accounts Departments in large railroads such as

the Northwestern, Illinois Central and New York Central, for prorating.

The following is a typical freight claim problem, in which the commodity has been carried over several roads and the loss or damage has to be prorated on a mileage basis.

THACHER

		Mileage	*Amount of Loss or Damage.*	
Given	C. & N. W.	1,628	$28.05	Read on Thacher.
	I. C.	4,261	73.42	
	C. & E. I.	825	14.22	
	C. R. I. & P.	2,270	39.11	
	C. B. & Q.	1,084	18.68	
	Total M.	10,068	$173.48	Total loss or damage.

SLIDE RULE (SIZE 20-INCH PREFERABLE)

		Mileage	*Amount of Loss or Damage.*	
Given	N. W.	172	$ 2.44	Read on Slide Rule.
	I. C.	364	5.17	
	C. & E. I.	258	3.67	
	R. I.	765	10.88	
	C. B. & Q.	98	1.39	
	Total M.	1,657	$23.55	Total loss or damage.

When the individual buys a ticket for passage over several railroad lines, the company that receives the total amount for the ticket has to prorate that amount over the several mileages traveled on each road, and this can be done quickly in the same manner as the above prorations. The New York Central has sixteen of the Thacher Slide Rules for this purpose alone.

The question is often asked if calculating machines are not faster in operation than the slide rule. For certain types of problems, they are, of course, excellent; but for problems such as those just described, there is nothing that will approach the slide rule in speed of operation. Any calculating machine must perform each operation of division and multiplication involved in proportions, or prorations, separately. When using the slide rule, an infinite number of equivalent proportions can be read after the first setting is made and no further manual operations are required.

Mr. S. L. Shelley of the Babson Statistical Organization, writing on the "Value of the slide rule in Business," states that his secretary in 2 1-2 days worked over 10,000 separate calculations which would have taken at least a week on a calculating machine and three weeks by long hand.

From this it can be seen that the Slide Rule is not a low-

priced substitute for the calculating machine but performs a distinct service which cannot be approached by any other method.

While the problems in railroad prorating just described generally have no more than six readings per setting, the problems in allocation of costs encountered by such concerns as the U. S. Gypsum Co. have as many as 50 proportions which are to be read from a single setting. These, when worked on the Thacher or the slide rule, can be solved with even a greater saving of time than the railroad prorate problems, as only one setting has to be made for every fifty readings. An actual test made at the U. S. Gypsum Co. showed that with problems involving about thirty prorates each, an average of twelve prorates per minute could be read.

In the following prorate problems encountered in allocation of costs in manufacture, such as those discussed above, thirty or more items generally make up the total but only a small group is given herewith, which will suffice as an illustration.

THACHER

	Cost per Article, Material, etc.	*Expense of Specific Operation.*	
Given	$ 46.85	$ 4.57	Read on Thacher.
	38.72	3.77	
	59.61	5.81	
	108.75	10.59	
	243.20	23.70	
	84.53	8.24	
	49.58	4.83	
	174.63	17.02	
	$805.87	$78.53	Total Expense.

SLIDE RULE (10-INCH)

	Cost per Item, Material, etc.	*Cost of Process.*	
Given	$ 3.65	$ 1.27	Read on Slide Rule.
	4.82	1.68	
	2.97	1.03	
	1.85	.64	
	6.23	2.17	
	5.16	1.79	
	4.07	1.42	
	1.28	.45	
	$30.03	$10.45	Total cost of process.

A third very important and common type of problem encountered in prorate is that of determining the percentage of various expenses in relation to the whole. In solving problems such as these, it is merely necessary to set the index (1) of the sliding scale coincident with the total expense (or whatever the particular problem might specify) and the correspond-

ing percentages are read adjacent to the individual amounts. Thus, in the following problem, the index on the sliding scale would be placed adjacent to 4984 on the stationary scale and adjacent to 1084 on the stationary scale would be found 21.75% on the sliding scale. It will readily be seen that any number of individual percentages can be read with only a single setting of the slide; and the saving of time in determining these percentages on the slide rule, as compared with a calculating machine, is remarkable.

In a large department store in Chicago, there are over 150 departments whose sales percentages must be calculated with relation to the whole. In a case such as this, there are over 150 percentages read with a single setting. On a calculating machine, 150 operations would have to be performed.

THACHER

	Expenses of each Department.	*Percentages Found.*	
Given	$ 768.25	15.41	Read on Thacher.
	423.48	8.50	
	165.23	3.31	
	575.18	11.55	
	1,758.37	35.27	
	209.64	4.21	
	1,084.39	21.75	
	$4,984.54 Total expenses	100.00%	

SLIDE RULE (10-INCH)

	Expenses.	*Percentages.*	
Given	$ 34.53	9.64	Read on Slide Rule
	62.40	17.42	
	17.23	4.82	
	45.81	12.79	
	23.75	6.63	
	174.33	48.70	
	$358.05 Total Expenses	100.00%	

The problems listed so far have been limited to proration, and the numerous calculations of combined multiplication and division, continued multiplication, continued division, percentages and ratios that occur daily in office practice, have not been touched. There are so many every day problems encountered in office work, which can be solved to advantage on the slide rule, that many business houses, such as Libby, McNeil & Libby, Swift & Co., Armour & Co., Commonwealth Edison Co., Western Union and Telegraph Co. of New York, General Electric Co. and others, give instruction in the use of the slide rule and make use of it constantly in their accounting and other departments. The time which can be devoted, however, to teaching employees the use of this instrument is,

of course, very limited and the employee must, if he wants to master it, devote quite a little outside time to practice on it. Even then, it is seldom that an employee becomes as skillful in the use of the slide rule as if he had learned its operation in high school.

The slide rule is not an automatic calculating machine but requires early practice to operate skillfully, and the young boy or girl of 14 and 15 in high school will more quickly become adept in operating the slide rule than will the employee in business who has become used to other methods of calculating. It is for this reason that a large number of important business men have put forth the plea that "ordinary" folk (as differentiated from technical students) be given training in the use of the slide rule in their high school days before they enter business.

The question of accuracy is one that bothers some people before they appreciate the real use of the slide rule. A member of the faculty of one of the best schools of commerce in Chicago, appreciating how often this question is raised, includes in a plea for a more universal instruction on the slide rule, the following:

"The point should be emphasized that, regardless of the size of the number, only the first three or four numerals are important, as that is as far as they can be read—particularly in percentages and multiplication in round numbers; for that is sufficiently accurate for all business purposes."

The above statement of "multiplication in round numbers" should not be misinterpreted to be a denial of the need for greater precision in billing where the charges to a customer must be carried out to the cent's place; but there are numerous multiplications and divisions encountered in everyday business routine where the slide rule produces results sufficiently accurate for the requirements.

To illustrate a problem of frequent occurrence in many industries, is the figuring of expenses allotted to a certain department over a specified period of time, given the yearly allowance. Here the business house itself is not interested in cents or even single dollars. If $3,648.00 is the annual allowance for a certain department, it is necessary to divide by 52 and multiply by 5 to find the limit of expenditure for a period of five weeks,

The problem, $\frac{3648 \times 5}{52} = 351$, or \$351.00 requires only a single movement of the slide and a reading, on the 10-inch rule.

Further, for the series of multiplications and divisions that estimators, buyers, and salesmen have to perform quickly, there is no more convenient device. Slide rules are used to advantage in figuring chain discounts, inventories, insurance premiums, interest, dividends, etc. Even banks use them, provided there has been a pioneer to introduce them. In most of the business houses mentioned above, an engineer who has left his profession for a managerial position is usually responsible for the introduction to the others, who have never had to use slide rules in school.

Recently a well known banking house in Chicago requested a slide rule lecture to a group of twenty young men in the Real Estate Loan Department, in which a few of the executives had already found the slide rule indispensable. Their calculations are numerous and varied, and the 10-inch size gives sufficiently accurate results for their needs. One of their most common problems is the appraisal of real estate by multiplying the cubical content of a building by the specified rate per cubic foot, and then determining the percent the required loan is to the estimated value of the property. For example, if a building is 35 ft. by 125 ft. by 56 ft. at \$0.35 per cubic foot, the three multiplications, facilitated by the use of the reciprocal scale, are performed almost instantly to give the price of the property as \$8,580.00 on the 10-inch. Then if \$2,000.00, for example, is the amount of the required loan, it can be divided by 8580 to give 23.3%, with one movement of the slide.

Now, with regard to ratios and percentages such as were encountered in the prorations previously given, the slide rule produces answers of as great accuracy as is usually required in general business practice. Regardless of the size of the numbers involved in a ratio, the three or four left-hand figures in each number are the only ones that affect the final answer. To the number of places to which the slide rule can be read, it is absolutely accurate. Consider the ratio $\frac{1283465}{3959521} = 32.4\%$, which is the answer that can be read on a 10-inch. Even were this ratio solved by long-hand or on a calculating machine, no change would be noticed in the first three digits. It is true that

a greater number of decimal places could be determined by the latter two methods, but those after the first three are of no interest to the average business man and would be discarded by him. It is well to note here that the final figure in a slide rule reading is never altered by any subsequent one that might be determined by long hand. Thus, if a result were calculated out to 14.6782, the slide rule reading would be 14.68.

The fact that large business houses such as those mentioned conduct slide rule classes on company time; the fact that the National Committee of Mathematical Requirements recently recommended its instruction to high school students for a better presentation of quantitative data and relationships; and the fact that some high schools are already actually conducting slide rule instruction to non-technical students, with considerable success—all combine to show the importance of slide rule as a subject of regular class instruction in secondary schools.

BASIC LIFE STUFF DESCRIBED.

Protoplasm, the stuff that makes things alive, was described by Dr. Robert Chambers, professor of microscopic anatomy at Cornell Medical School, in a lecture at the Manhattan Trade School. Rapid advances are being made in our understanding of the chemical and physical foundations of life, the speaker said, and every day the secrets that lie in the living cell are more intimately penetrated.

Protoplasm, as Dr. Chambers described it, shows itself under the microscope to be a clear, colorless material, sometimes viscidly fluid like the white of a raw egg, sometimes firm and jelly-like. But whatever its state, it always shows three properties so long as it is not dead: it grows, it moves, it can "feel"—that is, it can respond to stimuli. Nothing that is not alive can do any of these three things.

Although protoplasm is necessarily present wherever life is present, it is divided into such tiny masses, each within a cell wall, that it cannot be collected into large quantities for ordinary chemical analysis without killing it, when it would, of course, no longer be protoplasm at all. It is therefore necessary to carry on all researches on it by means of powerful compound microscopes. Because of this limitation on research into the properties of living matter, scientists could learn nothing at all about it until the microscope was invented, and that occurred only as recently as the seventeenth century. It has, therefore, come to pass that gross physiology, wh ch deals with the activities of the body in general and can be studied with the naked eye, aided by ordinary chemical and physical apparatus, got a much earlier start than microscopic physiology, which pries into the secrets of the tiny particles of protoplasm themselves. This situation, however, is rapidly being changed, for the science of microscopic physiology, especially during the last half of the nineteenth century and the first quarter of the twentieth which has just ended, has been making great strides to overtake its older companion.—*Science News-Letter.*

THE CHANGE OF ORIGIN FOR VELOCITIES.

By Hiram W. Edwards,

So. Branch, Univ. of Calif., Los Angeles.

This article is written with the purpose of calling the attention of teachers of mechanics in colleges and high schools to the advantageous use of an old device in the field of the vector addition of velocities. As far as the writer is aware the method described is mentioned in only one text book of college physics*, and in no high school text. The device is useful, it gives a better generalized view of the particular field to which it is pertinent and is easily understood by any student who appreciates vector methods of graphical representation of velocities.

Students do not experience any difficulty in solving, by vector methods, those problems which are of the type form:

$$V_P(F) = V_M(F) + V_P(M)$$

(in which the symbolic expressions may be read—the velocity of a point P referred to a fixed reference system (F) is equal to the velocity of a moving system (M) referred to the fixed system plus the velocity of the point (P) with respect to the moving system) provided the left hand number is to be determined. The following problem will serve to illustrate this type:

In a wind blowing north with a speed of 60 feet per second an airplane is flying at an angle of 45° east of north with an air-speed of 100 feet per second. Find the resultant velocity (ground-velocity) of the airplane. See Fig. 1.

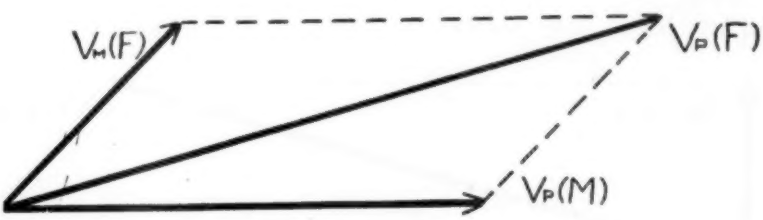

Fig. 1

It is obvious that here the two terms of the right hand member of the above equation are given and the velocity of the airplane with respect to the earth (the fixed system) is to be determined. The solution follows the well known rule of the

*Slate-Mechanics.

polygon or parallelogram method of construction, and no difficulty is encountered. By far the greater proportion of problems given are of this type.

In a few problems the left hand member and one of the other terms are the known elements with the remaining term to be determined. Such is the case in the following problem.

A train is going along a straight track with a speed of 100 feet per second. A bullet is shot along a line which is perpendicular to the track with a speed of 2000 feet per second and passes through the two walls of a coach. Find the path of the bullet through the train and its speed with respect to the train.

The student encounters difficulty with this problem. He tries to add the vectors as he did in the first problem and usually fails because he does not know a general method of solution. If he were supplied with the symbolic formula given above and knew how to add two vectors graphically when one of them is negative, he would not have to resort to a trial and error method of drawing the vectors, but could proceed with the same assurance of arriving at a correct solution as he did when solving a problem of the first type.

It is because the formula is adaptable to either type of problem that its use is recommended. In any given problem, it then becomes only necessary to identify each term of the formula with the vector element which should be associated with it.

In the problem just given it is evident that $V_P(F)$ may represent the velocity of the bullet. $V_M(F)$ stands for the train's velocity and $V_P(M)$ is the symbol which expresses the velocity of the bullet with respect to the train (the moving system).

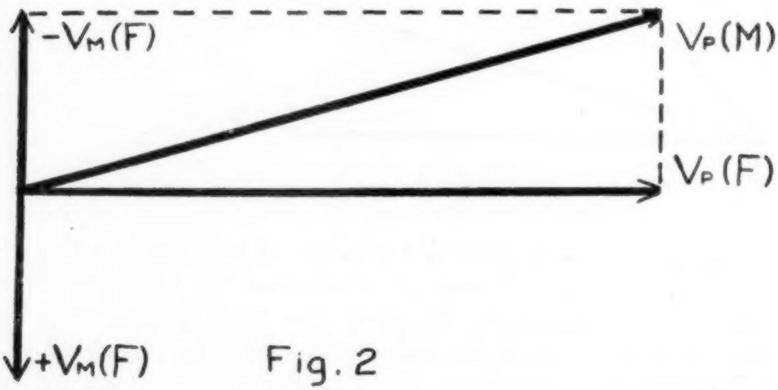

Fig. 2

Writing the equation so that it is explicit for the unknown term we have:

$$V_P(M) = V_P(F) - V_M(F).$$

Graphically this is represented as shown in Fig. 2 in which the vectors are not laid off to scale.

The validity of the formula may easily be established by the following argument. In the diagram, Fig. 3, XY is the reference (fixed) system, and X^1Y^1 is the moving system. The motion of the moving system is restricted to pure translation, hence its axes will always be parallel to those of the reference system. The coordinates of M are $x_o y_o$ and those of P in the moving system are x^1 y^1 and in the reference system they are x y.

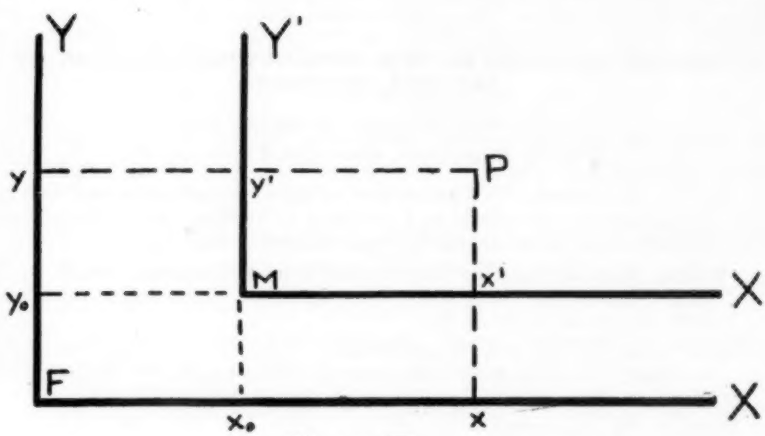

Fig. 3

The coordinate relations are:

$$x = x_o + x^1, \text{ and } y = y_o + y^1$$

If we differentiate each of these equations with respect to time, the corresponding velocity components are obtained.

$$V_x = V_{xo} + V_x{}^1 \qquad V_y = V_{yo} + V_y{}^1$$

Adding these equations and putting the resulting expression in vector form, the following result is obtained,

$$V_P(F) = V_M(F) + V_P(M)$$

in which each term is the vector obtained by adding its x and y components.

That this result may be extended to three dimensions of space is readily apparent. It may also include two or more moving systems in which the velocities of all but one are re-

ferred to another moving system and the velocity of one to the reference system.

By differentiating the coordinate relations twice with respet to time the corresponding accelerations are obtained and from them a vector equation expressing the acceleration of a point with respect to a fixed system in terms of the acceleration of the moving system plus the acceleration of the point referred to the moving system. This equation gives us an expression in accelerated motion which corresponds to the one given above for velocities. Its use has not been extensive for it is usually more convenient to use the dynamical element force in place of the kinematical quantity acceleration.

SPRING MEETING OF THE LANGLEY ASSOCIATION OF SCIENCE TEACHERS.

Saturday Morning, April 23, 1927.

Schenley High School, Room 109, Pittsburgh, Pa.

9:00 A. M. Address. A Comparison of the Demonstration and Individual Laboratory Methods in Chemistry as Determined by Non-Standard Objective Tests, David B. Pugh, Schenley High School.

9:30 A. M. Address. The High School Science Program. Dr. J. A. Foberg, Chairman, Curriculum Service, State Department of Public Instruction, Harrisburg, Pa.

10:00 A. M. Address and Demonstration. What Science Has Contributed to Lessen the Poison Gas Hazards in Industry, E. H. Kellogg, Sales Manager, Mine Safety Appliances Company, Pittsburgh, Pa.

10:40 A. M. Discussion.

11:00 A. M. Adjournment to the Auditorium of Schenley High School for the General Meeting of the Western Pennsylvania Education Association.

Dinner Meeting.

Thursday Evening, April 28, 1927.

English Room, Fort Pitt Hotel, Pittsburgh, Pa.

6:30 P. M. Joint Dinner of the Science Organizations of the Western Convention District of the P. S. E. A. Toastmaster—Dr. William M. Davidson, Superintendent of Pittsburgh Public Schools.

Address. The Art of Seeing Things, Dr. S. C. Schmucker, Professor Emeritus Biological Sciences, State Normal School, West Chester, Pennsylvania.

Every science teacher of the district is invited to attend the dinner. Members of the Langley Association are urged to be present. This dinner will be largely attended by representatives of every branch of science teaching and our association must be out in force. Reservation should be made in advance. Assessment is $2.00 per plate. Send checks to Frank W. Murphy, Secretary of the Langley Association, Oliver High School, Pittsburgh, Pennsylvania.

A GENERAL SCIENCE PROJECT ON SEWAGE DISPOSAL.

BY AMY L. COATS,

Barbour Intermediate School, Detroit, Mich.

The city of Detroit is planning to spend $100,000,000 (over a fifteen year period) for the construction of a sewage disposal system. The supervisors and teachers of General Science felt that our pupils should know something about this project. To arouse interest in Detroit's sewage disposal problem among a group of 8B General Science pupils was found to be a difficult task. After several unsuccessful attempts to impress the class with the importance of this subject, it was suggested that we write a play. In this play was to be one character who was uninterested and obstinate concerning the problem of sewage disposal. The purpose of the other characters was to convince this one person of the importance of this problem. The pupils wrote letters to the Board of Health and to the members of the City Council. The booklets which the pupils received contained interesting and useful material. A large outline map of the city was drawn, showing the locations of the proposed sewers, interceptors and disposal plant. The pupils gave their reports from memory, and seemed to enjoy giving them, because they were taking parts in a play. At the close of the semester our play was given in the auditorium as a part of the special Assembly program.

"CONVINCING HAROLD."

Time: One Saturday afternoon during the fall semester, 1926.

Place: In Detroit at the home of Virginia and Harold, brother and sister.

Characters: VIRGINIA, HAROLD, Members of their Science Class, GRANDMOTHER, LOUISE, who lives in Chicago, and a group of swimmers.

HAROLD: (*Coming into the room where* VIRGINIA *is seated at the table reading.*) What are you reading, Virginia?

VIRGINIA: (*Not answering immediately.*) Pardon me, Harold, for not answering your question sooner. I was so interested in reading this article on sewage disposal. We are going to give our reports Monday, you know, in Science class.

HAROLD: Sewage disposal! Oh, I am so tired of hearing about that subject that I don't know what to do. I have heard about it in Social Science class, I have heard about it in Exact Science class, and I have heard about it in English class. I don't see any sense in looking up reports on Detroit's sewage problem. I don't intend to bother myself about it anyway. It will be taken care of someway.

VIRGINIA: Don't you think, Harold, as future citizens of Detroit, it is our duty to acquaint ourselves with this important problem? If the sewage of the city is not properly taken care of, our drinking water is likely to become contaminated, which means the possibility of an epidemic of typhoid fever or some other disease.

HAROLD: Well, I don't want to hear anything about it anyway. I told you that I am tired of hearing about sewage disposal.

VIRGINIA: I am sorry, Harold, that you are not interested in this problem. I have invited the Science class over this afternoon. I am the chairman of the class, you know. We are going to read our reports to each other. Perhaps the class can convince you that Detroit's sewage disposal is an important problem. (*Doorbell rings.*) Here they come now.

HAROLD: (*Starting toward the door.*) No, it isn't the Science class, it is somebody else. (*Opens the door, and the crowd of swimmers enter.*)

CROWD: (*Carrying swimming suits.*) Hello, Harold! Hello, Virginia!

VIRGINIA AND HAROLD: Hello, everybody!

GEORGE R.: We thought we'd have a swimming party this afternoon, and we want you two to join us.

HAROLD: Oh, that will be great! I think we can go. I'll go and ask Grandmother. (*Leaves to ask Grandmother.*)

(*Crowd talk, laugh and act excited.*)

GRANDMOTHER: (*Enters, reading a newspaper, Harold following.*) A swimming party! Well! Well! (*Folding the newspaper and removing her glasses.*) I do hate to deny a good time to boys and girls, but health comes first, my dears. I have just been reading that recent tests of the water at the swimming beach show that the water is contaminated with disease germs. It is unfit for swimming. It seems that too much sewage has been dumped into the river. I don't believe that any of you should go in bathing today.

(*Children give a big sigh.*)

HAROLD: Grandmother, did they used to talk so much about sewage disposal when you were a girl?

GRANDMOTHER: No, child, but it was not such a big problem when I was a girl. There were not as many people in the city of Detroit then. The water of the Detroit River was sufficient to take care of the waste; but now, since we have over a million people in our city, besides the people of the down river towns—River Rouge, Trenton and Wyandotte—a new system will have to be devised.

VIRGINIA: I have a suggestion that we call off the swimming party, and all of you stay here this afternoon. Our Science class is coming over to discuss this sewage problem, and to

read our reports which we are going to give in school next Monday. I am sure that you will like to hear the reports.

GRANDMOTHER: (*Rising to leave.*) Surely our city is going to be a better place to live in than it has been in the past, since our young people are becoming so interested in these important civic problems. (*Exit.*)

(*Doorbell.*)

VIRGINIA: (*Going to the door.*) Here they come now. (*Opening the door.*) Good afternoon, everybody!

CLASS: (*Coming into the room.*) Good afternoon, Virginia!

VIRGINIA: Every member is here. Isn't that splendid!

HERBERT: That shows that everybody is interested.

VIRGINIA: These boys and girls (*motioning toward the swimmers*) were going to have a swimming party this afternoon, but Grandmother just read that the water is contaminated, so they are going to stay here and hear our reports.

MARIE: I have brought my cousin, Louise, who lives in Chicago. Louise will tell us about Chicago's sewage problem, if you wish.

VIRGINIA: We shall be glad indeed to hear a report about Chicago's sewage problem. If we know what other cities have done, we can better solve our own problems. (*After all are seated.*) We shall all come to order, please.

MARJORIE: Madam Chairman.

VIRGINIA: Marjorie.

MARJORIE: I have found a very interesting topic in a book called "Living Things," an Elementary Biology.

VIRGINIA: We shall be glad to hear your report now.

MARJORIE: "Sewage is the waste matter, usually fluid, that accumulates in every locality where a large number of people dwell, whether it be a city, a summer resort or an army camp. The disposal of this waste is one of the great sanitary problems of every large community. Unless removed far from its source, or purified by some chemical process, it becomes a breeding place for germs of diseases as well as an unpleasant factor in the surroundings. There are various methods of sewage disposal. Sometimes it is emptied into streams that carry it to the ocean, from which some portion is almost certain to be washed back to shore. Sometimes it is piped into lakes, from which water for drinking is afterward obtained. Any method that discharges sewage into a running

stream or into a body of water which supplies a community's drinking water is a menace to public health.

Safe methods of sewage disposal demand that the sewage be treated in such a way that all its organic contents be oxidized. The method best adapted to a given locality can be determined only by a careful consideration of all the factors and conditions involved." (P. 421, "Living Things," by Arthur G. Clement.)

GERALD: Madam Chairman.

VIRGINIA: Gerald.

GERALD: I have a report on Water Supplies that I think has a very close connection with the problem of sewage.

"One of the greatest assets to the health of a large city is pure water. By pure water we mean water that is free from all organic impurities, including germs. Water from springs and deep driven wells is the safest water, that from large reservoirs the next best, while water that has drainage in it, river water for example, is unsafe.

The water from deep wells or springs if properly protected will contain no bacteria. But water taken from a river into which the sewage from other towns and cities flows must be filtered before it is fit for use.

Many cities take their water supply directly from rivers, some times not far below another large town. Such cities must take many germs into their water supply. Many cities, as Cleveland and Buffalo, take their water from lakes into which their sewage flows. Others as Albany, Pittsburgh, and Philadelphia, take their drinking water directly from rivers into which sewage from cities above them has flowed." (Hunter's "Civic Biology," pp. 383-385.)

CHRISTINA: Madam Chairman.

VIRGINIA: Christina.

CHRISTINA: "Sewage disposal is an important sanitary problem for any city. Some cities, like New York, pour their sewage directly into rivers, which flow into the ocean. Consequently much of the liquid which bathes the shores of Manhattan Island is dilute sewage. Other cities, like Buffalo or Cleveland, send their sewage into the lakes from which they obtain their supply of drinking water. Still other cities which are on rivers are forced to dispose of their sewage in various ways. Some have a system of filter beds in which the solid wastes are acted upon by the bacteria of decay, so that it can be

collected and used as fertilizer. Others precipitate or condense the solid materials in the sewage and then dispose of it. Another method is to flow the sewage over large areas of land, later using this land for cultivation of crops. This method is used by many small European cities." (Hunter's Biology, pp. 386-387.)

BERT: Madam Chairman.

VIRGINIA: Bert.

BERT: Five of us boys have worked together on our reports—George, Robert, Joseph, Walter and I.

VIRGINIA: We shall hear your reports next.

GEORGE: "Plenty of pure water for drinking and cooking is indispensable to man. The necessity for disposing of sewage has made this problem increasingly difficult. Sewage-polluted water is never entirely safe for drinking. The two must be kept separate. This is the main reason why so much money has to be spent to bring drinking water to our cities, and this is the reason why so much care is taken to prevent this same drinking water from becoming contaminated. Some of the smaller towns have not yet come to appreciate the value and importance of having pure water to drink. The result is frequent epidemics of sickness." (Smallwood, Reveley, Bailey, p. 626.)

ROBERT: "In every town and city where a general water supply is established it is necessary to provide means for the removal of the waste water. This water comes from homes, places of business, and various manufactories. Not only the wastes from the human body but also from the street washing, the waste products from the various factories, and the annual rainfall and snow are all added to the waste waters of a city or town. Such water is known as sewage." (Smallwood, Reveley, Bailey, p. 628.)

JOSEPH: "It is now known that there is an average of one hundred gallons of sewage daily for every inhabitant of a city. The daily sewage from homes averages about thirty gallons for each member of a family; but when we add the street flushing and wastes of various manufactories the total amount per capita is not far from the larger amount named. Thus for a city of 100,000 inhabitants, there will be about ten million gallons of sewage a day. What must be the daily average of sewage in our city?" (Smallwood, Reveley, Bailey, p. 628.)

WALTER: "The question of what shall be done with all this vast amount of sewage is one of the most difficult that cities are trying to solve. The cities that are located on or near the ocean or Great Lakes let their sewage run into them. Those that are built on a stream or river empty into this small body of water and the town farther down the stream does the same. Where does the sewage of our city go?"

BERT: "We take our drinking water from lakes and rivers, but strangely enough we pour our sewage into these same bodies of water. Large septic tanks are employed in some cities and villages, where all the sewage is allowed to ferment, with the result that all the disease germs are destroyed. The outlet from these tanks takes away the liquid part and pours it into lakes and rivers with practically no danger to public health. The solid portions from the tanks make good fertilizer for depleted soils. In time we shall come to prize our public health so much that we will not allow any sewage to pollute our rivers and lakes. This will come only with a keener sense of responsibility among all people for the preservation and conservation of health." (Smallwood, Reveley, Bailey, pp. 629-630.)

WANDA: Madam Chairman.

VIRGINIA: Wanda.

WANDA: I think the class would enjoy a report from our Chicago visitor.

VIRGINIA: Yes, I am sure we shall be delighted to hear from you now, Louise.

LOUISE: "In Chicago the problem was to find a place to empty the sewage so that it could not flow into the lake. This was very difficult to do because the streams flow into the lake. The problem was solved by reversing the current of the river, and by means of a canal the water was made to flow into a branch of the Illinois River. Although Chicago is in the basin of the St. Lawrence River, at the present time its sewage flows into the Gulf of Mexico. The current now flows from the lake into the mouth of the river and up the South Branch, where it enters a new canal, known as the sanitary or drainage canal. This canal is made wide and deep to serve as a ship canal as well as for drainage. In this way part of the water of Lake Michigan now flows into the Gulf of Mexico and carries with it the sewage of Chicago. * * * The construction of the sanitary canal cost more than $56,000,000.

Did it pay? Let us look at some of the facts. The City Health Department reports that during the ten years before the opening of the canal in 1900, the average annual death rate from typhoid was 68.8 per 100,000, but in the ten years following, the rate was only 22.3. It is calculated that this represents a saving of 8814 lives. The Health Department has calculated that the actual money value of these lives to the community was nearly $53,000,000. It will always pay any city to secure pure water at any necessary cost." (Caldwell and Eikenberry.)

VIRGINIA: We thank you, Louise, for giving us a report about your own city. We most heartily agree with your last statement that it will always pay any city to secure pure water at any cost.

DICK: Madam Chairman.

VIRGINIA: Dick.

DICK: There are two systems of sewage disposal which have been discussed recently in the Detroit newspapers. There are the tank system and the screen system. I have here some first hand information on the tank system. I shall read a paragraph from this booklet on Sewage Disposal which Dr. Vaughn of the Detroit Health Board sent to me. (*Reads paragraph.*)

PHILIP: Madam Chairman.

VIRGINIA: Philip.

PHILIP: I have some posters here which will help to illustrate the necessity for a sewage disposal plant in Detroit. (*Shows posters and map of the city which shows the location of the proposed sewer disposal plant, and interceptors.*)

VIRGINIA: Whichever system of sewage disposal Detroit finds to be the best, I am sure the members of our Science class will continue to be interested in this very important civic problem.

WANDA: Madam Chairman.

VIRGINIA: Wanda.

WANDA: I move that we adjourn until next Monday morning.

VIRGINIA: We are all adjourned.

MARTIN: (*One of the swimming party members.*) I'm glad we stayed for the science class meeting.

ERNEST: After Detroit gets a sewage disposal plant our swimming parties will not have to be postponed. (*Exeunt.*)

(*Virginia accompanies the children to the door while Harold is*

rummaging over the table to find a book.)

VIRGINIA: (*Returning.*) What are you looking for, Harold?

HAROLD: I'm looking for that book you were reading about sewage disposal. Where is it?

VIRGINIA: Here it is. I am glad we convinced you, Harold, that this problem is really important.

CURTAIN.

THE INTRODUCTION TO GEOMETRY.

BY TRUMAN P. SHARWELL, A. B.

Graduate Student, Teachers College, Columbia University, formerly Instructor in Mathematics, Bogota, N. J., High School.

Euclid was written for adults, not for children. We rush pupils too hurriedly into demonstrative geometry. Pupils should be more slowly accustomed to new geometric terms, to the use of instruments, to consecutive thinking, and to the necessity for proof.

Definitions are best taught inductively. The order of presentation should be, first, familiarity with the fact; then the formal statement of the fact; not the reverse order. The common constructions such as bisecting an angle, bisecting a line segment, erecting perpendiculars, constructing an angle equal to a given angle, and constructing isosceles and equilateral triangles, should be considered. The definitions should be learned incidentally through constructions.

One of the chief purposes of the introduction to geometry is to arouse the pupils' interest in geometry. One way to enlist their interest and create a favorable attitude is to tell them at the outset that the chief purpose of geometry is to teach them how to think, how to investigate and discover new facts for themselves, how to prove that what they believe is true. They *enjoy* convincing others that what they believe is true beyond doubt. Encourage pupil criticism; give the class a chance to express appreciation of good work—this is the greatest stimulus to the pupil.

The introduction at its best should be built around some organizing principle. For example, it might very fittingly be centered around the idea of symmetry. Besides serving to unify the introduction, the concept of symmetry is worthwhile in itself.

The introduction should gradually accustom the pupil to the distinction between hypothesis and conclusion. The work should foreshadow and gradually lead up to formal geometry.

To begin with the proof of the theorem on vertical angles deadens interest, for the proof fails to increase one's conviction of its truth. To start with the proofs of the congruence propositions is also fatal because of their difficulty at this stage of the game. The best procedure is to prove the congruence theorems experimentally and then postulate them. It is a mistake to have pupils write proofs early, for this is sure to result in discouragement. Pupils should be asked to give many proofs before they write one.

Supplementary References.

For progressive teachers who would like to become familiar with the best ideas that have been written on The Introduction to Geometry, I am appending three references which I consider the cream of the articles that have appeared on this subject in a period of over fifteen years.

1. H. J. Chase. *Experimental Geometry.* School Science and Mathematics, volume 8, pages 577-579 (October, 1908). Some practical suggestions as to the employment of the inductive or experimental method.

2. Jos. A. Nyberg. *The First Month of Geometry.* School Science and Mathematics, volume 21, pages 29-36 (January, 1921). How an unusually successful teacher introduces pupils to geometry. The method described is based not on logic but on the idea that nothing shall be introduced until the need for it has been shown.

3. P. Stroup. *Why Is It?* The Mathematics Teacher (New York City), volume 19, pages 169-173 (March, 1926). An approach for 10B geometry, pages 172-173.

PLANT MISSING LINKS.

Fossil remains of plants with leaves like ferns but with fruiting bodies that tie them up with seed plants, have been found in "coal balls" from a coal mine at Danville, Illinois, by Dr. J. Hobart Hoskins of the University of Chicago. A report of Dr. Hoskins' work will be published in an early issue of the Botanical Gazette. The fossils were embedded in hard masses of iron pyrite, which had to be ground down thin enough to transmit light before they could be examined with a microscope. These coal balls have long been familiar objects of study in Europe, but interest in them has been aroused in this country only in the last few years, when Dr. Hoskins' teacher, Prof. A. C. Noe, began to collect and make sections of them.—*Science News-Letter.*

A STANDARD SIZE FOR SCIENCE NOTE-BOOKS.

By Clarence R. Smith,

Professor of Physics, Aurora College, Aurora, Ill.

What size shall I use for note-books? This is a question which comes to every teacher of science. Sometimes the answer is given careful consideration and is based on a very specific need. More often any size within quite a range would do and a choice is made of a particular line on account of kind of paper, form of rulings, or style of covers. Often there may be little choice as to size or style and a selection is made simply of whatever is most available. In any case when the line of a certain manufacturer is chosen it must be adhered to throughout the course. The teacher may want a particular kind of graph paper which he finds elsewhere but the chances are that it will differ enough in size to prevent its use with the books he is using. A student by the end of his educational career may find that his collection of note-books is of about as many different sizes as he has had teachers.

There are many advantages which would arise if some one size could be recognized as standard and used by science teachers in general. Let the manufacturers compete as to quality, kind of rulings, style of fasteners, covers, etc., but let the size be one in universal use.

Tables of logarithms, mathematical formulae, physical and chemical constants, etc., printed on these sheets could be made use of by most science teachers if available in a size which could be incorporated in the regular note-book. Mimeographed instruction sheets for laboratory work and also published laboratory manuals of the loose-leaf type should be of the same size as the note-book to permit interleaving.

The advanced student, the research worker, the science teacher or whoever extends his study over several years of time will accumulate valuable notes and data which become quite voluminous. Some system of filing must be employed and it will then become especially apparent that if uniformity has been adhered to in size of paper used, much will be gained in convenience, economy and appearance.

The selection of what this standard size is to be should be based on careful considerations. The size 20x25 cm. has most in its favor and is the recommendation in this article.

In well organized libraries where loose sheets are filed, 20x25

cm. is a standard size. Melvil Dewey[1] in writing of index rerums says: "While the sistem can be applyd to slips or sheets of any size, there are literaly hundreds of accessories and conveniences exactly adapted to these 2 sizes [7.5x12.5 cm. and 20x25 cm.] which are used 10-fold more than all others combined; so it is folly to begin on another size, and lose the advantajes of this uniformity." He also states that "note-books ar best in this last form [20x25 cm.]." This size he also recommends for scrap-book sheets.

To find what is now on the market, the present writer recently determined the size of paper used in each of 29 different lines of laboratory note-books and loose-leaf manuals now offered for sale. Although this list is not a large one it can be regarded as fairly representative since the selections were made at random and include the more widely advertised and extensively used lines. The smallest book in this list was 13.3x18.1 cm. (5¼x7⅛ in.) while the largest was 21.6x27.9 cm. (8½x11 in.). The size occurring most frequently was 20.3x26.7 cm. (8x10½ in.). The mathematical average of the entire list was 19.9x25.4 cm. This is remarkably close to the convenient figures, 20x25 cm. It must be observed, however, that this average does not take into consideration the greater sale which some lines may have over others but is merely an average of the different lines offered for sale.

Gruenberg and Wheat[2] in a questionnaire sent out to teachers of General Science found that of 62 teachers who indicated a preference as to size of note-book, 55 indicated sizes which did not depart more than ½ in. from 8x10½ in. 18 teachers who answered most of their questions had no preference as to size of note-book.

It appears that 20x25 cm. agrees so nearly with the average now in use that most teachers would be able to change to it without any inconvenience and it is probable that this would meet with more general favor than any other one size which might be standardized. 20x25 cm. can be cut from ordinary printer's stock without excessive waste, or at least without any more waste than with most of the note-book sheets now in use.

After all the aggressive work which science teachers have done to promote use of the metric system, and considering the

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[1]Decimal Classification and Relativ Index (1922), Melvil Dewey.

[2]School Science and Mathematics, Dec., 1925, p. 938.

policy of this journal on the subject, surely no apology is needed for expressing in convenient metric units a standard size for laboratory note-books.

Since laboratory note-books are most often of the loose-leaf style, the advantages of uniformity could be increased by the adoption of a standard spacing of the holes used in fastening the sheets together. However, an agreement in this respect would probably be much more difficult to reach owing to the great variety of rings, strings, snaps, clamps, etc., used for fasteners. The writer has for many years used three holes along the long edge spaced with centers 9 cm. apart. If these holes are placed with centers 1 cm. from the edge, either ring or string fasteners can be accommodated.

Attention to detail is the key to modern efficiency. Think of a large library nowadays using catalog cards of any other size than the standard 7.5x12.5 cm! As teachers, we have always been entirely in line with the spirit of unification, standardization and cooperation. It is believed that the standardization of a size for laboratory note-books would add another step to our progress.

SEVENTH ANNUAL EDUCATIONAL CONFERENCE: OHIO STATE UNIVERSITY.

Section of Non-Biological Sciences.

Friday, April 8, 1927.

Morning Session, 9:30 O'clock, New Chemistry Building, Room 161.
Wm. Lloyd Evans, Chairman of Section.

1. "The Use of Graphics in Teaching General Chemistry," by Professor J. E. Day, The Ohio State University.
2. "Measurement of Chemical Attitude and Attainment of Freshmen in American Colleges," by Professor Jacob Cornog, The University of Iowa.
3. "National Research Institute of Chemical Education," by Professor Neil E. Gordon, Editor of Journal of Chemical Education, The University of Maryland.
4. "Demonstration of New Experiments." All teachers of the non-biological sciences are cordially invited to present by actual demonstration any new experiments which they may have devised in their teaching. This exhibition is also intended to include charts and models which have proven to be helpful in the presentation of these sciences.
5. Appropriate announcements will be made at the morning session with reference to a group luncheon.

Afternoon Session, 2:00 O'clock, University Hall, The Chapel.

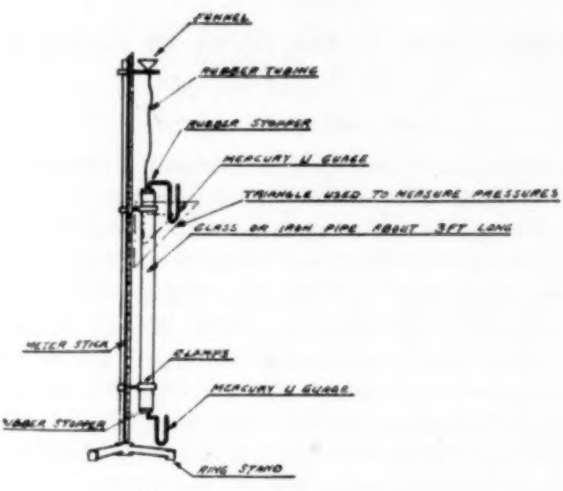
1. "Recent Ether-Drift Experiments and Their Interpretation," by Professor Dayton C. Miller, Case School of Applied Science.
2. "Recently Discovered Elements," by Professor B. S. Hopkins, The University of Illinois.

HOME MADE APPARATUS FOR DEMONSTRATING PASCAL'S PRINCIPLE AND PRESSURE OF LIQUIDS.

By Chas. F. Valentine,

Professor Physics, Colorado State Teachers College.

The apparatus described below was made by a couple of students in one of our physics classes. It is very simple to construct, gives excellent results and has such great possibilities in the class room that we feel we ought to share the idea with our fellow students and teachers. The apparatus gives both quantitative and qualitative results and is adaptable to demonstration as well as individual experimentation. The greatest thing in its favor, however, is its negligible cost. It can be made from parts ordinarily found in any laboratory.



PASCAL'S LAW & LIQUID PRESSURE APPARATUS

The illustration shows the essential parts of the apparatus which can be put together by any student. We have found that the following principles can be studied or demonstrated effectively and successfully.

1. The pressure of a liquid varies directly with the depth.
2. Comparison of densities of liquids such as gasoline, mercury, alcohol, water.
3. Pascal's Principle.
4. The U gauge.

5. The pressure of liquid is independent of shape or size of vessel.

An entire class period can be devoted to the demonstration and discussion of principles woven around the use of this apparatus. We have found that students have little difficulty in determining quantitatively the pressure of water at different depths, the comparison of densities of mercury and water, and Pascal's principle. It is our hope that a number of teachers will give this apparatus a trial. We should be glad to hear of other applications which may be discovered.

In reading the "U" gauges and height of liquid a triangle placed against the meter stick scale and U gauge increases the accuracy of the readings. Care should be exercised that no air bubbles are left in the apparatus.

BACKGROUND IN THE STUDY OF VALENCE.*

By G. T. Franklin,

Lane Technical High School.

No sooner are facts presented to the mind of vigorous imagination than system, order, arrangement into related groups begin to assert themselves. Theory is born to account for the facts. The starry sky gave to the primitive mind many facts upon which were based theoretical explanations. The mystery of changing season, rain, hail, lightning, the daily passage of the sun are familiar facts which stimulated primitive minds to invent theories to account for them. Theory becomes a law or a myth.

The facts of chemical reaction have long been the knowledge of man. Hypothesis and theory to account for chemical reaction have always constituted much of the science of chemistry. Modern measurements are constantly checking theory and by discovery open the road for new speculation. The hypotheses of Dalton are thus slowly becoming established laws with some modifications. It matters little to us whether Dalton formulated the atomic theory before the law of multiple proportions. The important thing is that the law of multiple proportions is in accordance with experimental facts and the atomic theory is easily deduced from the facts. The interesting feature is the large theoretical field, which it opened up to the investigator. According to the atomic theory matter is made up of small particles,

*Read at the Chemistry Section Meeting of the Central Association of Science and Mathematics, Nov., 1926.

which are the units of chemical reaction. Beyond this Dalton did not go. He must have foreseen that in order to understand the nature of chemical reaction, the unit must be understood. The importance of this unit, the atom, in modern chemistry is strikingly written by Duncan in his volume on "Some Chemical Problems":—"But about these ultimate particles of chemical reaction, or atoms, the evidence upon which the theory of their existence rests may be said to be all of chemistry, most of physics and a large part of every other field of natural knowledge."

It is quite apparent that the force which holds atoms together to make molecular matter is inherent in the structure of the atoms themselves and from the study of atomic structure facts are obtained, which give birth to theories of chemical affinity.

To what extent shall theory be taught? This much can always be said: The fact exists before the theory and if the fact is worth while in the scheme, the theory which relates the fact in the scheme is indispensable. If the pupil is given the fact without the theory, he will try to construct one of his own. The bright pupil is not satisfied with the mere statement of the fact. Now, valency is closely related to the fact of chemical reaction. The great bulk of chemical theory is more or less closely related to the study of valence. He, who would learn chemistry, must ground himself in the fundamentals. Atomic theory, electrostatics, corpuscular nature of electricity, chemical equivalents, structure of atoms, periodic classification of the elements, ionization and other topics are intimately connected with the study of valence.

The student of chemistry should be grounded in the general facts of electrification. In these days with its popular literature dealing with electricity and the general problem of interference in radio communication, there is an abundant opportunity and inducement to know something of the subject as general knowledge obtained outside of the classroom. The general science courses of the high school are invariably rich in the study of electrical phenomena. In many high schools the pupils have had the advantage of physics before studying chemistry. This is most fortunate for the chemistry teacher and on the basis of this knowledge it becomes easy to build. If, however, students are not familiar with the facts of electrification, they should be taught as part of the chemistry course. It is true the most recent developments tend to eliminate much of the use of electrostatics in the theoretical treatment of valence yet there are

certain phases that require its use. It probably represents the most tangible approach to the problem for the beginner.

The demonstration of the electrolysis of water is a favorite in general science classes. If, perchance, the pupil takes physics later he does the experiment accompanied by rather elaborate explanations. He learns the meaning of the word "ion" as a carrier of electricity. He should learn that some solutions conduct electricity while others do not and that the difference lies in the fact that one possesses electrical carriers and others do not. He may determine the electrochemical equivalent of a metal. This represents most excellent ground work in preparation for the study of valence.

What shall the chemistry teacher do with the electrolysis of water? All courses include it, although the puipl may have passed over it twice before. At the time when it is included in the chemistry course, all will admit, it is not proper to attempt a complete study of the chemistry of the reaction. The experiment may be used in any case to acquaint the learner with the charge of ions. His attention may be called to the fact that since twice the volume of hydrogen is obtained in comparison with the oxygen with the same electrical energy, and that in equal volumes there is an equal number of molecules, the electrical force of the oxygen must be twice that of the hydrogen. Here, too, is a splendid opportunity to ground in the knowledge that matter is made of atoms held together by electrical force.

As mentioned in a previous paragraph, the ultimate units of chemical reaction have in themselves the physical basis for the interpretation of chemical affinity, to understand the nature of which, the learner needs to know something of the structure of atoms. Popular literature is too full of matter descriptive of the electron for the pupil not to have read something on the subject before entering the chemistry class. A few minutes of discussion on the subject is always interesting. It is easy to apply the knowledge to interpret the constitution of matter. It is an easy step to the essentials of atomic structure. For the beginning student the knowledge sufficient for the purpose need include no more than the fact that atoms are built of positive and negative electricity, that the positive part of the atom is the nucleus, which includes the mass of the atom, around which electrons in orbital motions exist, a number equal to the net positive charge of the nucleus. It is necessary for him to know of electron shells and the condition of atomic stability, that

some atoms are stable by the nature of their construction and that all tend toward stability. This requires that some atoms need to acquire electrons and others lose electrons to reach stability. The relation between valence electrons and the classification of the elements cannot be overlooked at some point in the study and make it complete.

The problem of determining equivalent weights furnishes an ideal situation leading to an understanding of our general problem. Laboratory manuals invariably describe a method for rapid determination of the equivalent of one or more metals. To do the exercise for the sake of obtaining and remembering the number in itself, would of course, be using time rather questionably. When, however, the relation of the equivalent of the metal to its atomic weight is noted and the question why it is or is not the same propounded and answered, the way to the goal is opened up. The pupil obtains the equivalent weight of magnesium, for instance, and observes it to be one-half the atomic weight. It is assumed that the pupil has some acquaintance with the word "ion." He has learned that an acid property has to do with hydrogen ions. He has learned that when hydrogen ions are discharged it requires a cathode and that the result is the formation of gaseous hydrogen. He observes that when magnesium is covered with acid, hydrogen is liberated in the same manner as in electrolysis experiments. If his mind is active, he wonders if the two are the same, and if so, what gives the magnesium the electrical charge. His mind should be ripe to receive the information that the electrical effect is due to the passage of electrons from one substance to another, that magnesium atoms furnish electrons readily, which discharge the hydrogen ions, and the magnesium atoms in turn become the carriers of the electrical charge and therefore, in the ionic form. The mind of the pupil should be in a position to understand that while one atomic weight of magnesium replaces two atomic weights of hydrogen, the magnesium ion must carry twice the electrical charge. Here is a chance to do much ground work in fundamentals of valence based upon student experimental facts.

Having worked out the problem with a metal divalent in character, one monovalent or trivalent clinches the argument with more related data from which to draw inferences and extend knowledge.

It is not to be inferred that all knowledge mentioned so far

is essential to the beginning of the study of valence. Much of it is naturally fixed in the mind of the learner after he sees its need in chemical studies. It is a matter of common experience that a pupil is not grounded in any subject matter until he has used over and over again his knowledge to interpret problems. The study of oxidation and reduction reactions affords material for such problems. Balancing equations by comparing changes in valence of elements is excellent practice. A continued study of the elements classified, previously grounded in the study of valence bears better fruit.

Naturally polar valences receive the first attention of the beginning student. If he is grounded in the fundamentals of polar valence, however, it is but a step to an understanding of valence of non polar type such as exists in molecular hydrogen, nitrogen etc. In case he continues the study he has laid the foundation for the proper interpretation of structure dealing with large numbers of carbon compounds. The study opens up to him the facts upon which new theories are being built. He has been introduced to a field of speculative knowledge, which is without end.

THE DEAD SEA.

"The Dead Sea, known to all readers of the Bible, is the sink-hole of the world," says a bulletin from the Washington, D. C., headquarters of the National Geographic Society. "In no other continent is there such a deep depression in the earth's crust; nor will one find greater desolation or more uncomfortable conditions for man and most other living things even in the hearts of the greatest deserts."

The Land of Sodom and Gomorrha.

"The Hebrew scriptures have thrown an atmosphere of tragedy about this country. There, the chronicle states, were situated the wicked cities of Sodom and Gomorrha, destroyed by the wrath of Jehovah; and there the modern reader sees the blasted region, seared by unbearable heat, with its bitter death-dealing waters, to prove the story to his satisfaction.

"According to the Biblical narrative the Jordan Valley, and the plain near its mouth on the shores of the Dead Sea where the destroyed cities lay, shared the early good fortune of the Promised Land itself and 'flowed with milk and honey.' But an end was put to this pleasant condition by the rain of brimstone and fire.

Geology Indicates Vast Age.

"The story of the region deciphered from its rocks by geologists seems to indicate that Palestine and the whole western end of Arabia rose from the sea in what the geologists term the Tertiary era. Shortly after the rise, they say, a great slice of the land parallel to the coast of the Mediterranean sank to great depth, forming the huge rift valley, 'the Ghor,' now occupied by the Jordan River and the Dead Sea.

"It is not clear to geologists whether there was a connecting channel between the Mediterranean and the great valley; but a well defined ancient beach indicates that in those remote times the great depression held a sea or lake at about the same level as that of the Mediterranean. The Jordan did not then exist; its entire valley as well as the Sea of Galilee was swallowed up in the parent of the Dead Sea, which was some 200 miles long and 10 to 15 miles wide.

"It is believed that the climate of Palestine in remote times was moist and that the great inland lake was for a while kept at its highest point. When drier conditions set in the lake began to shrink, eventually retreating into the present position of the Dead Sea and exposing the valley now occupied by the Jordan. This is practically the only large river in the world which flows in a valley ready-made for it almost from source to mouth.

Five Times as Salty as Ocean Water.

"The Dead Sea depression having no outlet, all the salts contained in the large original inland sea were retained when evaporation reduced the volume of the body of water to its present dimensions. In addition, for ages the Jordan and the other streams and torrents that flow from the desert hills into the basin have been carrying in additional salts until now the waters of the Dead Sea constitute one of the most highly concentrated natural brines in existence. It is estimated that on the average some six million tons of water flow into the Dead Sea daily, and since the level of the sea changes but little, and there is no known outlet, an equal amount is pumped out daily by evaporation.

"Whereas ocean water contains about one-twentieth of its weight in dissolved solids, the solids in solution in Dead Sea water make up one-fourth its weight. Potassium chloride makes up about one-fifteenth of the total solids but common salt (sodium chloride) is fully five times as plentiful. The proposed isolation of the potassium salts, therefore, might be somewhat difficult on a commercial scale.

Old Volcano Near Sea.

"The present Dead Sea is 47 miles long and about 10 miles wide. Its surface lies approximately 1300 feet lower than sea level and at its deepest point its bottom lies another 1300 feet down. This great rift in the earth's crust, therefore, lies 2600 feet below sea level and is the deepest hole in the land anywhere in the world. Because of the intense heat and dryness and the presence everywhere of salt, the land immediately about the Dead Sea is a region of desolation. On some of the flats a few straggling, thorny desert plants grow and in some sheltered waddies where the springs are fresh, small groups of palms struggle for existence. Most of the area, however, is a dry, rocky waste encrusted with salt, or nearer the sea, slimy salt mud flats.

"Because the intense heat and pressure are almost sure to prove fatal to others than the few hapless Arab nomads that manage to survive in the region, this area has not been intensively studied by scientists. It was at first thought that there is no evidence of recent volcanic action and that the traditional destruction of the cities by a rain of fire and brimstone may have referred to the explosion of pockets of crude petroleum. A scientist who visited the region in 1909, however, reported a small extinct volcano near the northeastern corner of the Dead Sea near the reputed site of Sodom and concluded that a shower of ashes from this vent may have caused the catastrophe so vividly described in Genesis."

EXPERIMENTS FAVOR EINSTEIN.

Midnight balloon ascensions a mile and a half high made recently in Belgium may prove to be strong evidence in favor of Einstein's theory of relativity, and contrary to the results obtained by Dr. Dayton C. Miller, of the Case School of Applied Science at Cleveland, working at the Mt. Wilson Observatory in California, which were supposed by some authorities to be fatal to the German's theory. These balloon experiments, just published, were made by Prof. A. Piccard and Dr. E. Stahel, of the University.

They were a repetition of the Michelson-Morley experiment, named after the physicists who first performed it many years ago. This was intended to show whether or not the earth, on account of its motion, was drifting through the ether, which was supposed to permeate all space, and to be the medium in which light waves vibrate. When first performed, an almost negligible result was obtained. It was partly in an effort to explain this unexpected result that the theory of relativity was formulated. When repeated last year by Dr. Dayton C. Miller, of the Case School ofApplied Science, Cleveland, working at the Mt. Wilson Observatory in California, a mile above sea level, an apparent effect was found. While this was not as great as had been originally expected, Dr. Miller said that it could be explained by a motion of the sun, and the earth with it, towards the constellation of the Dragon, at a speed of over a hundred miles a second. This was antagonistic to the relativity theory.

In the new work, the Michelson-Morley experiment was repeated at sea level and from a balloon. A somewhat modified form of apparatus was used, in which the records were made on a photographic film, instead of by the eye, as in Miller's apparatus. As it is necessary to turn the apparatus while the experiment is in progress, so that it successively points in different directions, this was accomplished by providing the balloon with two small electrically operated propellors, turning the entire balloon about two or three times a minute. The illumination of the apparatus, which must be furnished by light of a single color, was obtained from the blue radiation of a mercury vapor lamp.

From measurements of the photographic records, it was found that there was an apparent ether drift of about four and a third miles a second. However, as the thermostat controls of the apparatus, intended to keep it at a constant temperature were designed to work with the thermometer below freezing, and since unexpectedly higher temperatures were found the night of the ascent, the results may be in error by an amount as great as the value found. However, it was stated, they show that the value of the ether drift does not increase, the higher above the earth the observations are made, which was the chief point of antagonism with the relativity theory.

What is said to be another new point in favor of the validity of Einstein's theory of relativity is contained in a series of experiments recently completed by Dr. Roy J. Kennedy, of the California Intitute of Technology, at Pasadena, and which have just been reported to the National Academy of Sciences.

Dr. Kennedy has also repeated the Michelson-Morley experiment with an improved form of apparatus, in which the beam of light, which is divided into two parts and then recombined, causing alternate light and dark "interference" bands, travels only about 13 feet, instead of more than 200 feet as in Miller's apparatus. The effect sought for is measured by means of a shift in these interference bands as the apparatus is pointed in different directions. With the instrument used by Dr. Miller, says Dr. Kennedy, a difference in pressure of a twenty-five thousandth of a pound per square inch in the air through which the two parts of the divided beam pass, would produce an effect as great as that observed. A temperature difference of a five-hundredth of a degree Fahrenheit would produce the same effect he stated.

As Dr. Kennedy's light path was so much shorter, there was much less chance of such error, and the entire apparatus was small enough to be completely enclosed in a sealed metal case containing helium gas, which

was at atmospheric pressure. This prevented circulation of the air, and any difference in pressure or temperature in different parts of the apparatus. By means of an improvement in the way of observing the interference bands, the instrument is as sensitive as Dr. Miller's despite the shorter light path. However, though "a shift as small as one-fourth that corresponding to Miller's would be perceived," said Dr. Kennedy, "the result was perfectly definite. There was no sign of a shift depending on the orientation. Because an ether drift might conceivably depend on altitude, the experiment was repeated at the Mt. Wilson Observatory, in the 100-inch telescope building. Here again the effect was null."—*Science News-Letter.*

WATER POWER AND IRRIGATION IN THE JEFFERSON RIVER BASIN, MONTANA.

The Mississippi-Missouri River system is one of the best known geographic features of the North American continent; it is the longest and one of the most important river channels in the world. This river system, including its tributaries, provides water supply for sustaining practically all of the commercial development in the interior plains of the United States and adjoining areas lying between the crest of the Rocky Mountains on the west, the Appalachian Highlands on the east, the Canadian boundary on the north, and the Mississippi Delta on the Gulf of Mexico. The ultimate source of this enormous chain of waterways lies in the Jefferson River Basin in Montana.

This headwater area was discovered and named by the Lewis and Clark expedition, which reached the mouth of Jefferson River July 25, 1805. It was nearly 50 years later, however, before white settlers entered the region in large numbers, and they were miners attracted by the discovery of gold there in the early fifties. During the heyday of mining activity great fortunes in gold were won, and in this connection much has been told of lawlessness and the heroic measures that were employed by the law-abiding citizens for the protection of life and property. At Virginia City, Mont., there still remain as a grim reminder of those early days the graves of bandits executed by the Vigilantes.

Today the Jefferson River basin has become a well-established agricultural region, although much of the land is rough mountain country of no agricultural value except for grazing. Here and there are broad open valleys and terraced benches that include large areas of tillable lands. The altitude of these lands ranges from 4,400 to 7,000 feet above sea level. At the higher altitudes, in general above 5,500 feet, the growing season is too short for diversified farm crops. At the lower altitudes a considerable variety of crops can be grown but there the rainfall is ordinarily inadequate for successful crop production, and irrigation has therefore been practiced extensively. The total area now irrigated is about 426,000 acres, and plans have been made for extending the irrigation development to include 185,000 acres more. At the present time storage reservoirs having an aggregate capacity of 113,000 acre-feet are operated, in connection with irrigation for the most part, and Government surveys have been made indicating that undeveloped sites having a potential storage capacity of 918,000 acre-feet are available for development.

There are also developed and undeveloped water-power sites in the basin, but these are of less economic importance than irrigation, largely because numerous water-power sites more easily and cheaply developed are available on other streams in that part of Montana, whereas the market for power is relatively small. The largest installed water-power

plant has a capacity of only 3,000 kilowatts and operation of that plant has been practically discontinued for the present.

The Department of the Interior, through the Geological Survey, has recently issued as Water-Supply Paper 580-B a brief report entitled "Water Power and Irrigation in the Jefferson River Basin, Montana," by J. F. Deeds and W. M. White, which contains a discussion of present and potential water power and irrigation development in the area. The report is illustrated by a map of the region showing the location of irrigated and irrigable lands as well as power and reservoir sites and also contains a summary of all available water-supply data obtained at the stream-gaging stations operated in this basin by the Geological Survey. —Department of the Interior.

OUR PROBLEM: TO EDUCATE 27,000,000.

A total of 27,398,170 pupils were enrolled in schools of every variety in the United States during the past year, and instruction was given by approximately 1,000,000 teachers, according to the annual report of the Commissioner of Education recently submitted to the Secretary of the Interior.

Citing further statistics regarding public education, the report shows the annual outlay for schools, both public and private, reached a grand total of $2,386,889,132, and the total value of school property was reported at $6,462,531,367. Concerning school buildings, it is shown that there are 263,280 public elementary and high-school buildings in the United States, of which number 157,034 are one-room schools. There are approximately 22,500 public high schools, 2,500 private high schools, 89 teachers' colleges, 114 State normal schools, 29 city normal schools, about 67 private normal schools, 144 colleges and universities under public control, and 769 under private control.—*School Life.*

IMMIGRANTS TO BE SHOWN U. S. AGRICULTURE IN FILMS.

Educational film productions of the United States Department of Agriculture will be used to promote Americanization of immigrants. Arrangements have been completed between the Office of Motion Pictures, of the United States Department of Agriculture and Will H. Hays, President of the Motion Picture Producers and Distributors of America whereby the Government films will be shown to immigrants arriving at American ports as a part of the Americanization service recently inaugurated by the film producers' organization.

The film program consists of pictures of historical, geographical and natural classification, including many leading feature productions of the industry. The four United States Department of Agriculture educationals selected are expected to assist in orientating the new Americans by acquainting them with the agricultural resources of the nation and with American farming methods.

KILAUEA GROWING UNEASY.

Kilauea volcano, the largest of known active peaks, is showing signs of uneasiness, according to Director T. A. Jaggar of the Hawaiian Volcano Observatory. The seismographs at Volcano House are recording frequent earthquakes, there has been a marked increase of avalanches into Halemaumau Pit, and there are yellow sulphurous patches on the slopes which are increasing in area.—*Science News-Letter.*

PROBLEM DEPARTMENT.

CONDUCTED BY C. N. MILLS,
Illinois State Normal University.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to C. N. Mills, Illinois State Normal University, Normal, Ill.

LATE SOLUTIONS.

947. *W. W. Wallace, Sacramento, Cal.*
948. *Michael Goldberg, Washington, D. C.*

SOLUTIONS OF PROBLEMS.

951. *Proposed by Daniel Kreth, Wellman, Iowa.*

Solve the following equation by Trigonometry:

$$336x^3+351x^2+62x-17 = 0.$$

Solved by George Sergent, Tampico, Mexico.

The given equation can be reduced to

$$y^3-20235y-1153350=0,$$

which is of the form $y^3-py-q = 0$. This equation has one real root and two imaginary roots. Take

$$y = k(r \tan A+r^2 \cot A),$$

where r is one of the cube roots of unity. Hence we get

$$y^3-3k^2y-k^3(\tan^3 A+\cot^3 A) = 0.$$

Setting up the three values of y, and identifying the equation with $y^3-py-q = 0$, we get $k = \pm\sqrt{6745}$, and

$$\tan^3 A+\cot^3 A = \frac{1153350}{6745\sqrt{6745}}.$$

Solving the last expression we get $\tan A = \dfrac{165\pm7\sqrt{5}}{2\sqrt{6745}}$.

Hence the values of y can be computed. Knowing the three values of y, we find the roots of the original equation to be 1/7, and $(-57\pm\sqrt{-15})/96$.

Also solved by *Chas. T. Oergel, State College, Pa.*

952. *Proposed by C. E. Githens, Wheeling, W. Va.*

From a heap of a pieces of money an nth part is taken after one piece is removed. After this had been repeated n times, the remainder is divided into n equal parts. How many pieces of money were there at first?

Solved by Michael Goldberg, Washington, D. C.

The remainder is a multiple of both n and $(n-1)$ and, hence, may be written as $n(n-1)x$. Working backward, the successive quantities are

$$\left[n(n-1)x\right]\frac{n}{n-1}+1 = n^2x+1;$$

$$(n^2x+1)\frac{n}{n-1}+1 = \frac{n^3x+2n-1}{n-1};$$

$$\left(\frac{n^3x+2n-1}{n-1}\right)\frac{n}{n-1}+1 = \frac{n^4x+3n^2-3n+1}{(n-1)^2};$$

$$\left[\frac{n^4x+3n^2-3n+1}{(n-1)^2}\right]\frac{n}{n-1}+1=\frac{n^5x+4n^3-6n^2+4n-1}{(n-1)^3}, \text{ etc.,}$$

The original quantity (T) is given by

$$\text{T} = \frac{(nx+1)n^n-(n-1)^n}{(n-1)^{n-1}} = \frac{(nx+1)n^n}{(n-1)^{n-1}}-(n-1).$$

Since n and $(n-1)$ are relatively prime, the quantity $(nx+1)$ must be made divisible by $(n-1)^{n-1}$. Then

$$nx+1 = m(n-1)^{n-1} \text{ where } m \text{ is an integer, hence}$$

$$x = \frac{m(n-1)^{n-1}}{n} = \text{an integer.}$$

When n is odd, m may be made unity, for $(n-1)^{n-1}-1$ is exactly divisible by n, that is, by $[(n-1)^{-1}]$. When n is even, m must be made $(n-1)$, then

$$x = \frac{(n-1)^{n}-1}{n} = \text{an integer, since then } (n-1)^n-1 \text{ is divisible by } n,$$

that is, by $(n-1)^1-1$.

Hence, when n is odd, the least value of $\text{T} = n^n-(n-1)$, and the successive higher values are found by adding multiples of n^{n+1} (Obtained by making $m = n+1$).

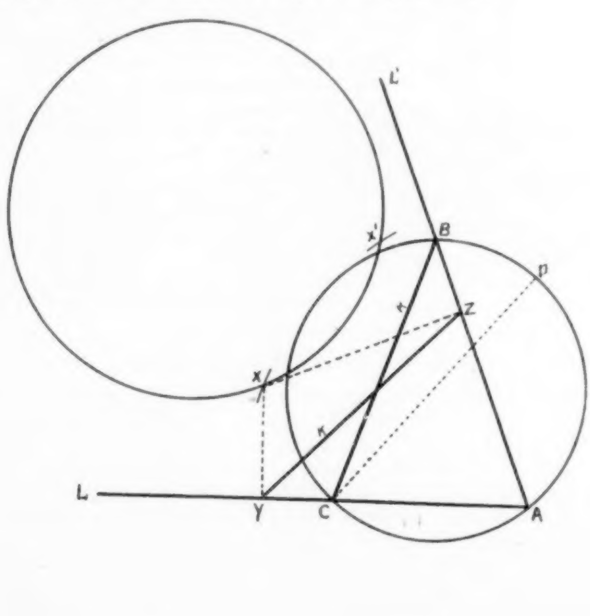
When n is even, the least value of $\text{T} = (n-1)n^n-(n-1) = (n-1)(n^n-1)$, and the successive values are obtained by adding multiples of n^{n+1}.

Incomplete solutions were received from *J. A. Nyberg, Hyde Park High School, Chicago; J. F. Howard, San Antonio, Texas; J. S. Georges, Chicago, Ill.; Franklin Clement, Grand Forks, N. Dak. L. R. Kellam, Culver, Ind.*

953 *Proposed by George Sergent, Tampico, Mexico.*

Given a circle O, and two lines L and L′ intersecting in A. From a point X on the circle, the perpendiculars XY and XZ are drawn to L and L′ respectively. Find X so that the line YZ, joining the feet of the perpendiculars, equals a given line, k.

Solved by Bessie B. Green-Andrews, Wichita, Kansas.



Draw a line the length of k, terminating in L and L'. Call the line CB. Construct a circle through the points A, B and C. The diameter of this circle is CD. With center A and radius CD draw an arc cutting circle O in X and X'. Either of these points is the required point.

Proof. The quadrilateral AZXY is cyclic since it has two opposite angles, right angles, and XA is its diameter for the same reason. This diameter equals CD. Since the circles are equal, the chords CB and ZY which subtend the same angle A are equal. Therefore ZY equals k.

Also solved by *Michael Goldberg, Washington, D. C.; F. A. Caldwell, St. Paul, Minn.; J. F. Howard, San Antonio, Texas;* and the *Proposer.*

954. *Proposed by J. F. Howard, San Antonio, Texas.*

A letter is known to have come from either London or Madison. On the postmark only the two consecutive letters ON are legible. What is the chance that it came from London?

I. Solved by Michael Goldberg, Washington, D. C.

The answer depends upon what events one assumes to be of equal probability. Suppose that the expectation of receiving a message from London is equal to that of receiving one from Madison. Then, in ignorance of its value, let p be the probability of the absence of any particular letter in the postmark (assuming it to be the same for all letters). The probability of the absence of all the letters except ON in MADISON is then p^5. For LONDON, the probability of a certain ON being the only vestige of the postmark is p^4, and the probability of either ON being the only remainder is $2p^4$. Therefore, the chance that it came from London is $2/p$ times the chance that it came from Madison. If there are no other possibilities, then the probability that it came from London is $(2/p)/(2/p+1) = 2/(p+2)$.

II. Solved by the Proposer.

There are six combinations of two letters each that might be made by a stamp, of which the combination ON is one. Hence, the chance of ON coming from Madison is 1/6. In London there are five combinations of two letters, of which two are ON. Hence, the chance of ON coming from London is 2/5. Therefore, the chance letter known to have come from one of the two cities is 2/5 to 1/6 in favor of London, or 12:5.

955. *Proposed by Walter C. Carnahan, Indianapolis, Ind.*

Solve:

$$x^3+y^3 = 8-z^3 \qquad (1)$$
$$x+y = 2-z \qquad (2)$$
$$x^2+y^2 = z^2. \qquad (3)$$

Editor. No solutions were received. The following solution is given: Cube (2) and subtract (1). This gives

$$xy(x+y) = -4z+2z^2. \qquad (4)$$

Square (2) and subtract (3). This gives

$$xy = 2-z \qquad (5)$$

Substituting value of xy from (5), and value of $x+y$ from (2), in (4) gives $z = 2$. Hence $xy = -2$ and $x+y = 0$. Solving the two last equations we get $x = \pm\sqrt{2}$, and $y = \pm\sqrt{2}$.

By dividing (1) by (2), then subtracting (3) we get $-xy = 4+2z$. Hence $z = \dfrac{-xy-4}{2}$. Substituting this value of z in (2) and (3) gives

$$x+y = 4+\frac{xy}{2},$$
$$4x^2+4y^2 = x^2y^2+8xy+16.$$

The solution of these two equations leads to the fallacy $48 = 0$. Noticing the values of x and y in first solution, we see that $x+y = 0$.

PROBLEMS FOR SOLUTION.

966. *Proposed by Norman Anning, Ann Arbor, Mich.*

Prove that if a triangle has two sides which are not equal its area can be increased without increasing its perimeter.

967. *Proposed by Smith D. Turner, Cambridge, Mass.*

Under what conditions can a number be equal to its logarithm?

968. *Proposed by Walter R. Warne, University of Minnesota.*

Given the base of a triangle, the vertical angle, and the bisector of the vertical angle, to construct the triangle.

969. *Proposed by J. Q. McNatt, Canon City, Colo.*

Given a circle of radius R. and its inscribed Decagon and Pentagon. Prove geometrically that square of the radius plus the square of the side of the Decagon is equal to the square of the side of the Pentagon.

970. *For High School Pupils. Proposed by P. H. Nygaard, Spokane, Wash.*

A rectangular field has a straight road running diagonally across it. The road entrances are on the long sides of the field. The road has the shape of a parallelogram. Its width is 4 rods, and the field is 80 rods by 160 rods. How many acres in the field?

ARTICLES IN CURRENT PERIODICALS.

American Botanist, January, Willard N. Clute & Co., Joliet, Ill., $2.00 a year, 50 cents a copy. Preparation of a Local Flora, Donald C. Peattie. The Meaning of Plant Names—XXIX Polemoniaceae and Hydrophyllaceae, Willard N. Clute. High-Bush Cranberry Again, Fannie M. Heath. Opening of the Primrose, Arthur Monrad Johnson.

American Journal of Botany, January, Brooklyn Botanic Garden, Lancaster, Pa., $7.00 a year, 75 cents a copy. The Structure and Development of the Cell Wall in Plants I. Bast Fibers of Boehmeria and Linum, V. C. Aldaba. Phytophthora blight of Citrus, Gerardo Offimaria Ocfemia and Emiliano F. Roldan. Cytological Studies of Crowngall Tissue, A. J. Riker. The Status of Saxifraga Nuttallii, Arthur Monrad Johnson. The Floral Behavior of Some Eriocaulaceae, J. C. Th. Uphof. The Bitternut Hickory, Carya Cordiformis, in Northern Minnesota, Arthur Monrad Johnson.

American Mathematical Monthly, December, Menasha, Wis., $5.00 a year, 60 cents a copy. On the Mechanical Handling of Statistics, Victor Johns, 50 Broad St., New York. The Great Treasure House of Chinese and European Mathematics, Pere Louis Vanhee, S. J., Brussels. The Kinetics of Learning, H. J. Ettlinger, University of Texas.

Condor, January-February. Bi-monthly. Cooper Ornithological Club, Berkeley, Calif., $3.00 a year, 50 cents a copy. The Surf-Bird's Secret, Joseph Dixon. Emargination of the Long Primaries in Relation to Power of Flight and Migration, C. K. Averill. Notes of the Location and Construction of the Nest of the Calliope Hummingbird, Winton Weydemeyer. Breeding Birds of Scammons Lagoon, Lower California, Griffing Bancroft.

Education, January, The Palmer Co., Boston, $4.00 a year, 40 cents a copy. The Need for a Social Psychology of Education, Elbert Vaughan Wills, Brooklyn, N. Y. The Social Aspect of College Entrance Restriction, Benjamin Deutsch, 1319 Clay Ave., New York City. Some Paramount Objectives of the Junior High School, Frederick E. Bolton, University of Washington, Seattle. Peace and the Public School, William G. Carr, Pacific University.

General Science Quarterly, January, W. G. Whitman, Salem, Mass., $1.50 a year, 40 cents a copy. Objectives as Determining Factors for Making a Course of Study in Junior High School Science, Zay Barber, University of California. Individual Laboratory Work versus Teacher Demonstration, Eliot R. Downing, University of Chicago. Creating Interest in General Science, J. A. Ernest Zimmermann, State Normal School, Shippensburg, Pa.

Journal of Chemical Education, February, Rochester, N. Y., $2.00 a year, 35 cents a copy. Photography as a Recording Medium for Scientific Work, Part II, G. E. Matthews and J. I. Crabtree, Research Laboratories, Eastman Kodak Co., Rochester, N. Y. The Vitamins, IV, H. C. Sherman, Columbia University, New York City. The Structure of Matter: A Brief Review of Present-day Conceptions, V. Up-to-date Chemistry in the General Chemistry Course, Maurice L. Huggins, Stanford University, California. The Pole Reaction Method of Teaching Oxidation and Reduction Reactions, H. L. Lochte, University of Texas, Austin, Texas. The Electromotive Series and the Periodic Table, John R. Sampey, Howard College, Birmingham, Alabama. Potash, R. Norris Shreve, Consulting Chemist, New York City.

Journal of Geography, January, A. J. Nystrom and Co., 2249 Calumet Ave., Chicago, $2.50 a year, 35 cents a copy. Cotton Manufacturing in the South, Howard Wilbur, William E. Russel School, Boston, Massachusetts. The Early Historical Geography of San Francisco, Eric P. Jackson, Hillsdale College, Hillsdale, Mich. The Geography of Imerina, Madagascar, Daniel R. Bergsmark, University of Minnesota.

Mathematics Teacher, December, National Council of Teachers of Mathematics, Yonkers, N. Y., $2.00 a year, 40 cents a copy. A Few Constructive Phases of Mathematics in Life, W. Paul Webber, J. P. Cole and R. L.

O'Quin, State University, Baton Rouge, La. Teaching Logarithms to High School Pupils in Eight Recitation Periods, Barnet Rudman, Pittsfield High School, Pittsfield, Mass. The Human Significance of Mathematics, William L. Schaaf, College of the City of New York. A Pleasant Approach to Demonstrative Geometry, E. V. Sadley, Minneapolis.

National Geographic Magazine, February, Washington, D. C., $3.50 a year, 50 cents a copy. A Maryland Pilgrimage, Gilbert Grosvenor, President National Geographic Society. The Heart of Aymara Land, Stewart E. McMillin.

Popular Astronomy, January, Northfield, Minnesota, $4.00 a year, 45 cents a copy. Elgin Observatory, W. W. Payne. The Occultation of Saturn, 1927, January 28, William F. Rigge. Morning and Evening Stars for 1927, Frederic R. Honey. Reading the Time from the Stars, L. M. Berkeley.

Science, January 21, Grand Central Terminal, New York City, $6.00 a year, 15 cents a copy. Leaf Structure and Wound Response, Robert B. Wylie, University of Iowa. Factors of Significance in the Development of European Agriculture, Jacob G. Lipman, New Jersey Agricultural Experiment Station. French Instruction and Research in Biology, Raoul M. May, American Field Service, Paris, France. February 4, Research as a Method of Education, A. J. Carlson, University of Chicago. The Bermuda Biological Station for Research, Inc., Herbert W. Rand, Secretary of the Corporation.

Scientific American, February, New York, $4.00 a year, 35 cents a copy. Building Blocks of the Universe, B. S. Hopkins, University of Illinois. Where was the Birthplace of Mankind? J. Reid Moir, Royal Anthropological Institute of Great Britain and Ireland. The Carbonization of Coal at Low Temperature, H. W. Brooks.

Scientific Monthly, February, The Science Press, New York, $5.00 a year, 50 cents a copy. Carl Akeley and His Work, Dr. Clyde Fisher, American Museum of Natural History. Has Einstein Killed Time? Alfred C. Lane, Tufts College. The Nature of Sciosophy and Science, David Starr Jordan, Stanford University. Transportation, Arthur Clinton Boggess, Baldwin-Wallace College. Gaps in the Mongolian Life Record, William K. Gregory, American Museum of Natural History.

School Review, January, The University of Chicago Press, $2.50 a year, 30 cents a copy. Statistics Which Should be Kept on File in the Office of the High-School Principal, Leighton S. Thompson, Edward F. Searles High School, Methuen, Massachusetts. The College Freshman's Range of Information in the Social Sciences, M. J. Van Wagenen, University of Minnesota. A Study of the Reliability of an Objective Examination in Ninth-Grade English, Edith L. Hammond, Greensboro High School, Greensboro, North Carolina. The Effect of Supervised Study in Kansas High Schools on Success in the University of Kansas, B. F. White, Superintendent of Schools, Little River, Kansas.

Teachers Journal and Abstract, January, Colorado State Teachers College, Greeley, Colo., $2.00 a year, 35 cents a copy. The Biggest Thing in Teaching, Frank M. McMurry. Whither Bound in Curriculum-Making, Earle Rugg and Paul McKee, Department of Education, Colorado State Teachers College.

BOOKS RECEIVED.

Plane Trigonometry and Tables by Herbert E. Buchannan, Ph. D., Professor of Mathematics in the Tulane University of Louisiana and Pauline Sperry, Ph. D., Assistant Professor of Mathematics in the University of California. Cloth. Pages xi+112. 23x15 cm. 1926. Johnson Publishing Co., Richmond, Virginia.

Work Book in General Science by Ellis C. Persing, A. B., Cleveland School of Education and Kimber M. Persing, B. S., Glenville High School, Cleveland, Ohio. Paper. Pages 127. 27.5x21 cm. 1927. The Harter School Supply Co., 2046 E. 71st St., Cleveland, Ohio.

The Buckingham-Osburn Searchlight Arithmetics, Introductory Work

by B. R. Buckingham, Director of the Bureau of Educational Research, Ohio State University and W. J. Oshurn, Director of Educational Measurements, State Department of Public Instruction, Madison, Wisconsin. Cloth. Pages xv+381. 19x13.5 cm. 1927. Ginn and Company. Price $1.00.

Applied Chemistry Experiment Sheets by Martin Mendel, Thomas Jefferson High School, Brooklyn, New York. Paper. 75 Exercises. 26.5x19 cm. 1926. Globe Book Co., 175 Fifth Ave., New York.

Arithmetic Work-Book, Grade 8 by G. M. Ruch, F. B. Knight, J. W. Studebaker and Edited by George W. Myers. Paper. Pages iv+76. 28x19.5 cm. 1926. Scott, Foresman and Co. List Prices: Pupils' Edition 36 cents, Teachers' Edition 48 cents.

Teacher's Edition Arithmetic Work-Book, Grade 7 by F. B. Knight, G. M. Ruch, J. W. Studebaker and Edited by George W. Myers. Paper. Pages xviii+74. 28x19.5 cm. 1926. Scott, Foresman and Co. Price 48 cents.

Housing the Children—A Community Project Prepared for The Board of Education, City of Hamtramck, Michigan. Paper. Pages 123. 23x14.5 cm. 1926.

The Sciences by Edward S. Holden, Revised Edition. Cloth. Pages x+224. 18.5x13 cm. 1927. Ginn and Co. Price 84 cents.

Plane Trigonometry, With Tables by Miles A. Keasey, M. A., South Philadelphia High School for Boys, G. Alfred Kline, M. A., South Philadelphia High School for Boys, D. Allison Mcilhatten, B. A., Girard College, Philadelphia. Cloth. Pages vii+130. 23.5x15 cm. 1927. P. Blakiston's Son & Co. Price $1.28.

Standard Service Arithmetics, Book Two for Grade 4 by F. B. Knight, University of Iowa, J. W. Studebaker, Superintendent of Schools, Des Moines, Iowa and G. M. Ruch, University of California. Cloth. Pages. xiii+441. 14.5x12.5 cm. 1927. Scott, Foresman and Co. Price 80 cents.

An Introductory Course of Mathematical Analysis by Charles Walmsley, M. A., Assistant Lecturer in the University of Manchester. Cloth. Pages x+293. 22x13.5 cm. 1926. Cambridge University Press, London.

Interpolation by J. F. Steffensen, Sc. D., Professor of Actuarial Science at the University of Copenhagen. Cloth. Pages ix+248. 23x14.5 cm. 1927. The Williams & Wilkins Co., Baltimore, U. S. A. Price $8.00.

Properties of Inorganic Substances by Wilhelm Segerblom, A. B., Instructor in Chemistry at the Phillips Exeter Academy. Cloth. Pages 226. 23x15 cm. 1927. The Chemical Catalog Co., Inc., 19 East 24th Street, New York.

BOOK REVIEWS.

Elements of Agriculture, by G. F. Warren, Cornell University. Pp. xx+549. 259 illustrations. Revised Edition. 1926. The Macmillan Company, Chicago.

The first edition of this text appeared in 1909. It served a valuable purpose in the earlier days of the teaching of high school agriculture and it was widely used as a text. This revised edition brings subject matter and methods up to date. The author expresses the opinion that the purpose in teaching agriculture is not to make farmers. It is a human interest subject. The underlying reason why such teaching is desirable is because it brings schools in touch with home life. It is the expressed purpose of the author to provide a text to form the basis of a course that should give every boy and girl an opportunity to learn if they desire the fundamental principles of plant and animal growth—not that they may become farmers or farmer's wives, but for the educational training and intelligent interest in life that this knowledge brings.

The author expresses the fact that the trend of much of our education at present is cityward. It may not be desirable to try to make farmers, it certainly seems desirable to stop unmaking them. While the teaching of agriculture will make better farmers, who will make more money, yet the great reason for the teaching of agriculture is that it is one of the best means of training the student's mind, because it deals with the things that come within his experience—the things with which and by which he lives.

Thought questions and content questions are added at the end of each chapter. A total of eighty-six exercises are given for laboratory work. Besides the discussions of crop plants and farm animals, there are chapters devoted to plant and animal improvement, plant propagation, plant nutrients, soils, and maintaining soil fertility. Chapters on farm management, the farm home, and the farm community give a cross-section view of farm life. The style and organization of this text will be appreciated by both pupil and teacher. Jerome Isenbarger.

Outline Manual, Elementary Science, Cleveland Public Schools, Committee of School Teachers, Ellis C. Persing, Chairman, assisted by Catherine S. Ross, Agnes Ziska, Margretta Morse, and Agnes Shipman with introduction by H. M. Buckley.

This outline manual is used in the kindergarten and the first six grades of the public school system in Cleveland. The material in the outline is being developed through experimentation by teachers in the classroom. The general aims are stated for each grade. Each unit is composed of a statement of objectives, questions and suggestions for pupil activities, with visual materials and suggested references. The units are organized on a seasonable basis whenever it is possible to do so. The units are also based on the environment and activities of pupils in the lower grades. The material for each unit is sufficient for a thirty minute class period.

Provision is made for revision as may be found necessary in classroom teaching. The teachers are asked to revise the manual through the consideration of the following questions—What objectives are repeated? Are sufficient activities listed to attain the objectives for each unit? Which teaching units are inappropriate to the grade? For what units are materials not available? What units should be eliminated and what units should be added? These questions are an indication of the thorough and scientific methods the teachers are using in the development of a course in elementary science. Each unit is well organized, the questions are practical, the visual materials suggested are easily attainable, and the references are sufficiently complete. There is also a complete list of reference material for each grade.

This experimental study of elementary science in the lower grades has been needed for a long time. The Cleveland teachers are to be commended for the excellent beginning they have made. The fact that the outline is so well organized, and still only tentative, speaks well for the future of elementary science in the lower grades of the Cleveland schools.

I. C. D.

Conquering the Air, by Archibald Williams. Cloth. Pages xiv+315. 20x14 cm. Thomas Nelson & Sons, New York. Price $2.00. 1926.

"Conquering the Air" is a book for every library. Here is adventure, travel, romance, history, invention, science and biography combined. Starting in 1783 with the first balloon which was made of paper lined with linen and filled with air heated by burning straw, the author has traced the story of aerial navigation thru the various steps made by balloon, aeroplane and dirigible to the present day, successful, regular air schedule for freight, mail or passenger service.

In some chapters the reader is permitted to hear the adventurers tell their own stories, thus being able in a slight measure to share the thrill of the explorer; in other scenes he feels the skepticism of the watching, curious crowd who view the flight from the ground. The Montgolfers, the Wrights, M. Bleriot and Count Zippelin become his acquaintances and friends. Just enough of the details of contruction and manipulation are given to show the difference between success and failure.

The various stories include the first flight across the Channel, crossing the Atlantic, from London to Australia, around the world, in the Polar regions, aircraft in war, and a chapter on the future of flying. The print is clear and the illustrations well-chosen. It is a good book for supplementary science reading, and the boy in the English class will really read it for his book review, unless his parents monopolize it for their own entertainment. G. W. W.

Fourfold Geometry, by David Beveridge Mair. Pp. viii+183. 15x22.5 cm. 1926. $2.75. New York. D. Van Nostrand Co.

"In consequence of the revolution produced in mathematical thought by the principle of relativity, geometry falls naturally into three stages. The first stage is the geometry of Euclidean space. The second stage brings the fourth dimension of the world into consideration and assumes the existence of straight lines. The third stage continues the discussion of the four-dimensional world and recognizes that straight lines do not exist and that their place is taken by geodesics. It is the second stage that is treated in this book."

To read the book one should be acquainted with the Cartesian method of treating geometry and with the meaning of conjugacy with respect to a conicoid.

J. M. Kinney.

What Arithmetic Shall We Teach? G. W. Wilson, Professor of Education, Boston University. Pp. ix+149. 12x18 cm. 1926. $1.20. Boston. Houghton Mifflin Co.

In this book Professor Wilson has brought together the scientific data, collected by many investigators, as to what is useful in arithmetic. These data have been collected from various communities scattered throughout the United States and from hundreds of different occupations.

From the standpoint of social needs this evidence collected indicates that a great mass of material now commonly presented in our arithmetics should be eliminated. Not only should many topics be omitted but the treatment of the fundamental operations should be greatly modified.

The author defends vigorously the thesis that the subject matter of arithmetic should be based upon the quantitative needs of the public. He believes that it is very doubtful if the schools, in the tool subjects, should go beyond adult usage or should attempt to indicate material or practices which might be superior to those in vogue.

Whether teachers of mathematics agree fully with this point of view, or not, they should give the book careful consideration.

J. M. Kinney.

Harmonic Curves, by William F. Rigge, S. J., The Creighton University, Omaha, Neb. 1926. Pp. 213. 6¼"x9½". Price $3.25.

The author of this charming book could not have been led to write it merely from the usual desire to do a little better what many another has done fairly well. Students of mathematics very well know that there

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is almost no literature on the subject of this book. Surely so pioneering a work so well done will call forth from many another student in the fields of harmonic motion and harmonic curves still further works to supply the present lack. If one would expose himself to the charms of the subject matter of harmonics, he could hardly do better than read this beautifully illustrated, simply written and cleverly organized book.

Mr. Rigge has done a real scientific service in publishing this little volume, the object of which as stated by the author is: "To present the subject of harmonic curves in its general outlines and in a somewhat popular form." Although sufficient mathematical grounding is given to the elementary principles to satisfy the mathematically inclined reader, to open to such a reader the further possibilities of the subject, yet the treatment is intelligible enough apart from the mathematics to furnish enjoyable study also to the non-mathematical reader. The avowed object of the book is "to encourage the study of harmonic curves" and there can be no doubt that the book will perform this function "handsomely."

After a few pages of preface in which the author states simply and fully the several aims of the nine chapter units, and the rather unusual but highly convenient plan of the organization of the contents and of the numbering of the subunits of the chapters, he treats the following topics: Simple and Compound Harmonic Motion, The Mathematics of Harmonic Curves; Plotting; Machines; Cycloids; Beauty, Artifices and Surprises; Stereoscopic Harmonic Curves; Analysis of Curves; A Few Harmonic Curves.

Then follows an appendix containing the following four papers by Mr. Rigge, reprinted from *The American Mathematical Monthly*, viz.:

Concerning a New Method of Tracing Cardiods,
Cuspidal Rosettes,
Envelope Rosettes,
Cuspidal Envelope Rosettes.

The typography and paper are excellent, typographical errors are scarce and such as there are can be readily corrected by the reader.

The author's unique "block system" of numbering the paragraphs of the preface and the paragraphs and chapters of the body of the book will appeal to some as a clever device for enabling the reader to turn readily to any topic he wants and to locate it readily on the page, all from its section numerals.

The profuseness and charm of the wonderful drawings of the Creighton Machine, here reproduced, cannot fail to impress the reader with the almost uncanny possibilities of this "wonder-working" machine. Students of mathematics and physics of both high schools and colleges will find much to thrill and delight them in this book. G. W. M.

Principles of Plant Growth, an elementary botany, by Wilfred W. Robbins, Associate Professor of Botany, College of Agriculture, University of California. Cloth, 5x8½ in., 299 pp., illustrated with 130 cuts. Published by John Wiley & Sons, Inc., New York. 1927. Cost $2.25.

This book is designed to give information for the orchardist, nurseryman and farmer, as well as for the use of teachers and students. It is planned to be useful also for the Smith-Hughes high schools. With this in mind the author has given a great deal of attention to answering practical questions which arise in the practical operations of the farm, orchard and garden.

We think the author has succeeded very well in his purpose. A casual examination of the text yields these suggestive topics: "Root systems and cultivating machinery"; "The purpose of pruning"; "The healing of wounds"; "Ragdoll Tester"; "Seeds as carriers of disease," and many more of similar nature. We note also that the language is simple and direct. The illustrations are especially useful and illustrate. We think this book a great improvement in botanical texts for high school and well worth careful consideration by teachers. It can do much toward bringing back a measure of popularity for botany as a high school study.

W. Whitney.

Smith's Inorganic Chemistry, Revised and rewritten by James Kendall, Professor of Chemistry and Administrative Chairman of the Department of Chemistry, Washington Square College, New York University. Pp. xxv+1030. 15x21x3.5 cm. Illustrated. Cloth. 1926. The Century Co., N. Y.

As we open this new revision the genial countenance of one who wrote admirably, and who taught better than he wrote, greets us from the frontispiece. His works do follow him. Prof. Kendall has left much of the best of Alexander Smith's work in the present volume but this time Kendall has added liberally of his own good store and has brought the text thoroughly up to date. For example, the Smith explanation of valence in the early part of the book has had superposed upon it the modern electronic explanation, later on in the text again, the treatment of electromotive chemistry carries with it the electronic explanation of the nature of the reactions. Oxidation and reduction are explained in terms of removing or adding electrons.

While no special chapter is given over to colloid chemistry there are sections devoted to the subject in connection with the chapter on Animal Life and Animal Products and Food.

Radio activity and atomic structure receive very thorough attention and the chapter is excellently illustrated.

Organic chemistry is briefly touched upon in the chapter on Hydrocarbons and their Derivatives as well as in the chapters on Plant Growth and on Animal Products.

In fact we have here a veritable encyclopedia of inorganic chemistry which should make the book an invaluable addition to the reference library of many a high school chemistry department as well as a fine text for college use, for which purpose it was written. Professors who have the general course to teach should obtain and consider this new college text.

F. B. W.

Elementary Principles of Chemistry by Brownlee, Fuller, Hancock, Sohon and Whitset, all of New York City. Revised. Pp ix +596+20 (of index) 14x19x2 3-4 cm. Illustrated. Cloth. 1926. Net price to schools, $1.20 plus transportation.

The outstanding feature of this new edition of a well and favorably known high school text book of chemistry is its early introduction and use of the modern theory of sub atomic structure. After some 50 pp. of discussion of oxygen, hydrogen and water the notion of atoms is introduced together with that of molecules. Symbols and formulae are then taught. Chlorine and hydrochloric acid next serve to give the pupil a few more facts and then molecular composition, atomic and molecular weights are presented. Then, on page 117 and the next 20 or so pages we have an excellent presentation of the subject of electrons and valence.

Those who have been struggling to formulate some plan of attack on the problem of how best to teach and apply the modern ideas as to the structure of the atom will be grateful to the authors for the splendid elementary presentation of the essentials of this topic. The use of the figure of speech that suggests that the metals are "lenders" of electrons while the non metals are "borrowers" is very helpful to the beginner. The cuts showing diagrammatically the essential features of the subatomic structure of some dozen or so of the simpler atoms and the relation of this structure to the valence, whether positive or negative, of the atoms are very helpful also. Some application of the notion of electrons is made when the nature of electrolysis is explained in a later chapter but the authors have, perhaps wisely, refrained from explaining how the notion may be used in connection with oxidation and reduction.

Another noteworthy contribution to the new edition is the chapter on colloids. The matter is well selected and well presented.

The good features of the previous edition have, of course, been retained and much new material added. Gram molecular volume is given as 22.4 liters thus basing all chemical calculations on oxygen as 16.

The practical applications of the subject are well taken care of and the illustrations are excellent and up to date, as a look at the frontispiece

will reveal (It shows Prof. Hopkins X ray apparatus for the identification of the characteristic lines of Illinium.)

All high school teachers of chemistry will want to see this new text.

F. B. W.

BURNING ATOMIC HYDROGEN.

By Edwin E. Slosson.

A chemical combination that produces greater heat than any hitherto known has been discovered by Dr. Irving Langmuir of the General Electric Company.

For over a hundred years the highest heat attainable by combustion was that produced by the burning of hydrogen in an atmosphere of oxygen. But Langmuir has found it possible to get a higher temperature by the unprecedented process of burning hydrogen in an atmosphere of hydrogen. In the oxyhydrogen blowpipe, commonly used for welding or the limelight, two atoms of hydrogen united with one atom of oxygen to form a molecule of water. In the new Langmuir blowpipe two atoms of hydrogen simply unite with each other to form a molecule of hydrogen.

The novelty of the process consists in the possibility of producing a stream of hydrogen gas in the form of single and separate atoms instead of paired atoms, in which hydrogen has been hitherto handled. The coupled hydrogen atoms are divorced by passing a stream of the gas through an electric arc. The apparatus is simple, and looks like the ordinary blowpipe that you see used in welding or cutting steel on the street car track. It is held in the hand and the point of the flame directed on the metal while the head of the operator is enclosed in a helmet to protect the eyes and face from the intense light and heat.

A stream of hydrogen from a small copper tube is driven between the tips of the two tungsten electrodes and projects a double flame several inches long. The inner flame consists of atomized hydrogen burning in molecular hydrogen, while surrounding this is a flame of molecular hydrogen burning in air.

A tungsten wire stuck into the tip of the inner flame melts and drops off like an icicle in a gas jet. Now tungsten is a metal so refractory that it required many years of experimentation to find a way of getting it sufficiently softened so that it could be drawn into filaments for electric lamps. Its melting point is over six thousand degrees Fahrenheit, so the temperature of the flame of atomic hydrogen is doubtless more than seven thousand.

If the blowpipe is turned upon the tip of a cone of alumina, the refractory ingredient of clay and porcelain, this melts down like a tallow candle in a Bunsen burner. If a sheet of steel or other metal is rolled into a tube the seam can be welded without solder by simply running the blowpipe along the joint. When the flame plays on a plate of chrome steel it leaves a string of puddles in its track.

The heat is higher than that of the familiar oxy-acetylene blowpipe though not so high as in the electric arc itself. Dr. Langmuir suggested that we may in time get rid of the rattle of riveting which annoys the neighborhood when a skyscraper is being constructed, and the welded joints of the steel frame would be stronger since no holes need be bored in it.

A further advantage of the new flame is that the metals heated by it are not oxidized, since they are completely enclosed in hydrogen gas. This makes it possible to weld such light metals as aluminum and magnesium, which when heated in air fall into white powder.

BEYOND EINSTEIN.

Mathematics lies at the basis of all the other sciences and a science is regarded as becoming most scientific when it can be treated by mathematical methods. Astronomy and physics reached the mathematical stage first, chemistry is rapidly following suit and recently biology and psychology are making use of mathematics. On account of the fundamental importance of mathematics any advances in this field are welcomed by investigators in every field of research.

Consequently it is not surprising that the thousand dollar prize offered for a notable contribution to the Christmas sessions of the American Association for the Advancement of Science at Philadelphia, is awarded this year to Prof. G. D. Birkhoff of Harvard, for his mathematical paper entitled "A Mathematical Critique of Some Physical Theories." Although the committee contained no representative of the Mathematical Section it picked his paper from the two thousand that were read during the week.

Only professional mathematicians will understand its significance and it is impossible to present its formulas in ordinary type. So all that can be done here is to show what the paper is about and why it is considered important by experts.

Geometry was developed into a perfect logical system by the Greeks and until the nineteenth century was taught exclusively as the last word in this science. But recently it has been found possible to develop other systems of geometry, equally consistent within themselves. This raised the question whether the Euclidean geometry or some of its newer rivals, the non-Euclidean geometries, best fitted the world as it is. When Einstein pointed out that the non-Euclidean geometry gave a better explanation of other physical phenomena, mathematicians plunged into the new field with greater zest.

Professor Birkhoff has taken a step beyond Einstein. He accepts the four dimensional view of space and time embodied in the theory of relativity as "reasonably correct qualitatively" but points out that no way has yet been found to account for all the lines of the spectrum of light, which are ascribed to the frequency of vibration of various parts of the atom. The atom was formerly regarded as simple, but is nowadays regarded as composed of positive and negative electrical particles, called protons and electrons, the unlike bodies attracting and the like bodies repelling each other.

But Professor Birkhoff proposes the use of a new type of elastic body and the "new assumption that the electrical forces between the charges on one and the same proton or electron are attractive instead of repulsive." The laws of space and time in the atomic domain seem irreconcilable with the known statistical laws that can be directly verified but he hoped that "the mathematicians would develop various types of mathematical universes which might subsequently be of aid to the physicist."

For the second time in its four years of existence, the thousand-dollar annual award given at the winter meeting of the American Association for the Advancement of Science has gone to a mathematician.

Dr. Birkhoff was born in Michigan in 1884. He first entered college at the Lewis Institute in Chicago, but received his bachelor's degree at Harvard, in 1905, followed by an M.A. in 1906. He returned West, however, for his doctorate, receiving it at the University of Chicago in 1907. He taught at the University of Wisconsin and at Princeton, until Harvard called him back in 1912; since 1919 he has held full professorial rank there.

He has written much on mathematics, especially on relativity, and has been editor of two mathematical journals. He is president of the American Mathematical Society, and has received recognition abroad by the Circolo Matematico di Palermo, the Royal Danish Academy of Science and Letters, the Göttingen Academy of Sciences and the Royal Institute of Science, Letters and Arts of Venice.—Science News-Letter.